UNITED STATES

TENNESSEE VALLEY AUTHORITY

THE DOUGLAS PROJECT

A Comprehensive Report on the Planning, Design, Construction, and Initial Operations of the Douglas Project

TECHNICAL REPORT NO. 10

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TENNESSEE VALLEY AUTHORITY,
Knoxville, Tenn., June 16, 1948.

MR. GEORGE F. GANT, *General Manager,*
Tennessee Valley Authority, Knoxville, Tenn.

DEAR MR. GANT: The accompanying report covers the planning, design, construction, and initial operations of the Douglas project. It has been prepared by the engineering and construction staff with contributions from a large number of persons from other divisions of the TVA and forms a companion volume to the previously issued technical reports on other TVA projects.

Inasmuch as Douglas was constructed in record time under pressure of the World War II emergency, it has received perhaps more than average attention by the public and by technical men generally. It is recommended that this report be printed as a public document.

Yours very truly,

C. E. BLEE, *Chief Engineer.*

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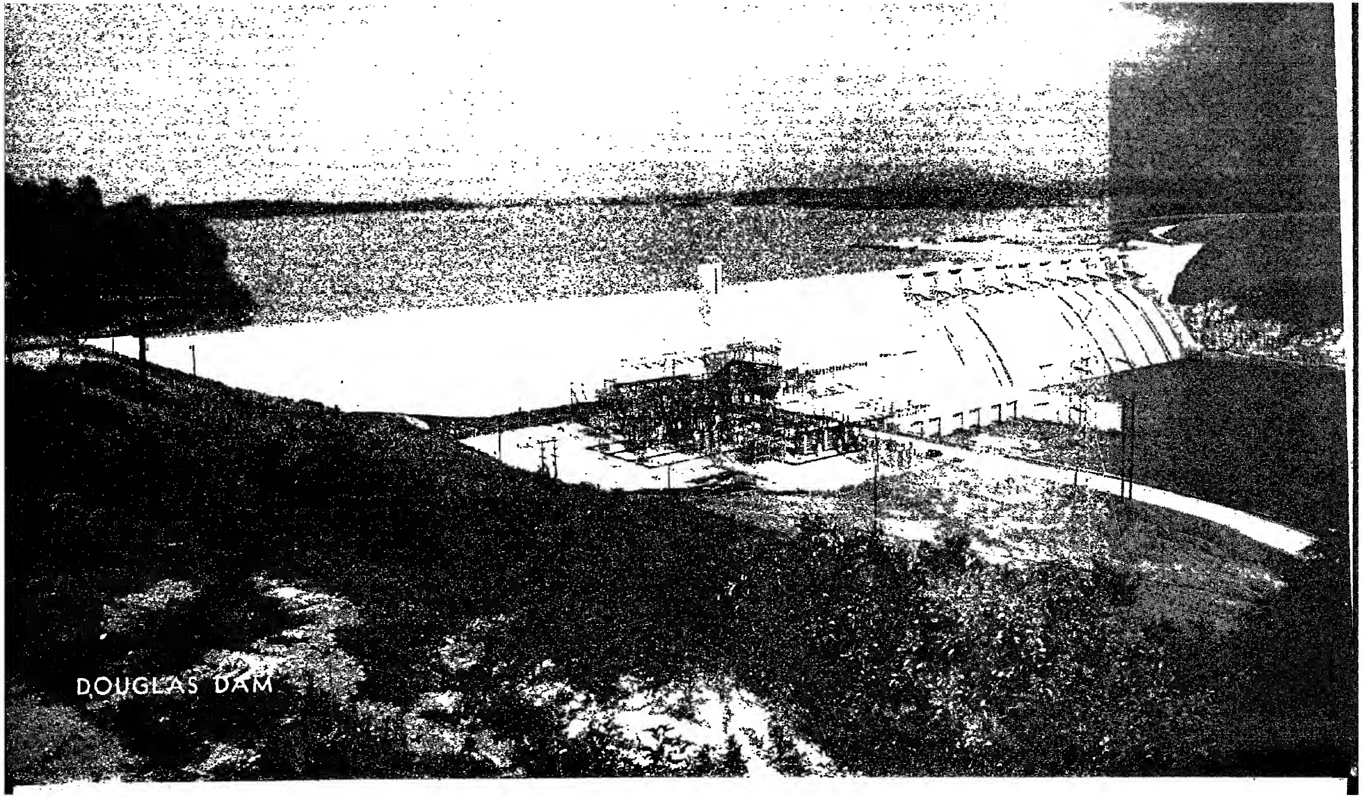
DOUGLAS DAM

THE DOUGLAS PROJECT

CHAPTER 1

INTRODUCTION

Two major tributaries, the French Broad and the Holston, unite just above Knoxville to form the main Tennessee River. Projects constructed by TVA on these two tributaries made an important contribution to the war effort of the United States during World War II by making blocks of badly needed power available at crucial stages of the conflict. The Douglas project, whose name was derived from Douglas Bluff, located on the French Broad about 32 miles above its confluence with the Holston, controls a drainage area of 4,541 square miles.

The Cherokee project on the Holston River, only about 20 miles from the Douglas site, was the first of several TVA dams authorized under the World War II emergency program. It was constructed on an emergency basis in 16 months and established a major construction record. Later, Douglas was authorized by Congress on January 30, 1942, and construction was started February 2. It was rushed to completion on an emergency schedule and placed in operation in only 13 months. The speed with which it was constructed, in spite of difficult foundation conditions and 4 weeks' delay as a result of two major floods, is believed to be a new record for a project of this magnitude.

The power plant has an installed capacity of 60,000 kilowatts and provision has been made for the installation of an additional 52,000 kilowatts. Although operated primarily for power during the war emergency, Douglas forms an integral unit in the over-all system of water control projects in the Tennessee Valley, and under normal multiple-purpose operation aids in reducing main-river flood stages and stabilizing low-water flows.

The events leading up to the construction of the Douglas project illustrate the thorough investigation which preceded congressional authorization and actual construction of this project. As in the case of previous authorizations of emergency programs, this addition to the TVA system was recommended following a Nation-wide survey by the War Department, the Office of Production Management, and the Federal Power Commission.

In 1936, in its report to Congress on the unified development of the Tennessee River, the TVA Board of Directors pointed out that to provide for—

complete and effective navigation and flood control on the Tennessee and Mississippi Rivers, dams to provide substantial storage on the Holston and French

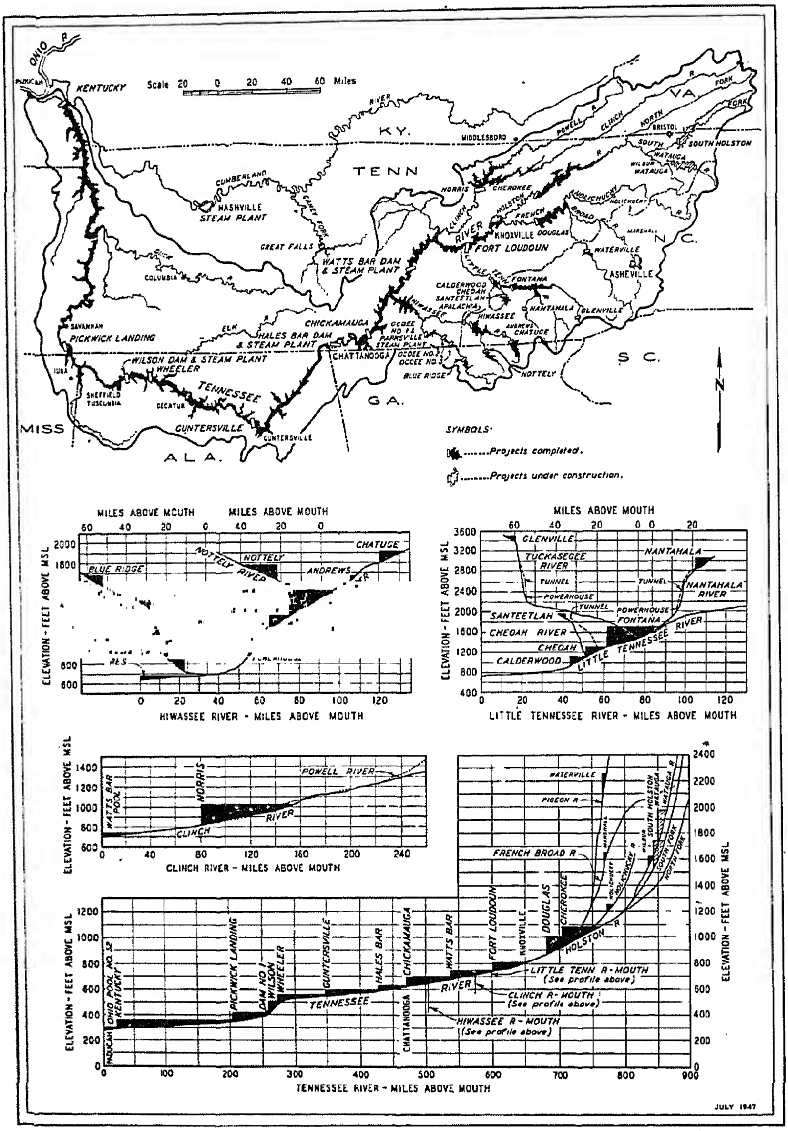

FIGURE 1.—*Map and profile of the Tennessee River system.*

Broad Rivers should be provided when their construction is justified. Preliminary surveys indicate that a reservoir having a capacity of about 900,000 acre-feet may be feasible on the French Broad River near Dandridge * * *[1]

[1] The Unified Development of the Tennessee River System, Tennessee Valley Authority, March 1936, p. 23.

In 1939, the TVA in a report on the Chattanooga flood-control problem described the beneficial effects of increased storage capacity on tributary streams. One of the sites studied was the Douglas site.[2]

Although recognized as a project that would control a drainage area substantially greater than that controlled by any other tributary project developed, under construction, or available for construction in the Tennessee Valley, recommendation for the construction of a multipurpose dam at Douglas was deferred by TVA because of the complex problems attendant upon the creation of a large reservoir on the lower French Broad. Above the site lay a fertile, populous, and prosperous agricultural region, long settled and highly developed. Well adapted to the production of vegetables, it contributed to the support of a sizable canning industry. Construction of the project would inundate over 15,000 acres of bottom land and would flood or require the acquisition of some 18,000 acres of less productive lands.

With the outbreak of war in Europe in 1939 and the entrance of the Nation into a state of emergency, the probable need for the immediate large-scale expansion of power-generating facilities was emphasized. To make readily available the information on feasible power projects in the Tennessee Valley, the chief engineer prepared a report, *Possibilities for Hydroelectric Development—Upper Tennessee Basin*, in which he stated:

> Development of the Douglas site on the French Broad River would provide low-cost power but would result in the destruction of a prosperous agricultural area, and for this reason might not be desirable. Where equal possibilities exist without elimination of agricultural lands, the other possibilities should be developed first.

When the report was later revised, the Douglas development was described as—

> one of the most desirable additions which can be made to the system for power purposes only or for combined power and flood-control purposes.

Again its construction was not recommended because of the problem of complex agricultural readjustment that would arise with the flooding of the area. Therefore, when asked by the Office of Production Management in March 1941 to suggest what could be done to increase the continuous power supply in the Valley,[3] TVA described several possibilities but omitted the Douglas [illegible].

Although TVA's primary reason [illegible] recommending the Douglas project when it did was the urgent need for power in the defense program, as discussed more fully later, the project is not a war-born expedient. It was designed and constructed as a multiple-purpose project, a unit in the long-range unified plan for the development of the Tennessee River system.

Unified plan

The Tennessee Valley Authority Act[4] provides for a 9-foot navigation channel from the mouth of the Tennessee River to Knoxville; the control of floods; the generation of power incidental thereto; and other related public benefits. In March 1936, the TVA submitted

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[2] The Chattanooga Flood Control Problem, H. Doc. No. 91, 76th Cong., 1st sess., 1939, pp. 43–44.

[3] Hearings before the subcommittee of the Committee on Appropriations, House of Representatives, 77th Cong., 1st sess., on H. J. Res. 194, pp. 6–8.

[4] Tennessee Valley Authority Act of 1933, sec. 4 (j), sec. 9a, 48 Stat. 58, 61, as amended by 49 Stat. 1075, 1076.

TABLE 1.—*Principal features of water control projects*

Project	Dam and appurtenances							Power [4]	
	Date of first use	River	Maximum [1] height (feet)	Over-all crest length (feet)	Maximum [2] spillway capacity (cubic feet per second)	Volume of concrete (cubic yards)	Volume [3] earth and/or rock fill (cubic yards)	Installed or under construction (kilowatts)	Ultimate capacity (kilowatts)
Kentucky	1944	Tennessee	206	8,422	1,049,000	1,359,000	7,159,600	160,000	160,000
Pickwick Landing.	1938	do	113	7,715	650,000	630,300	2,966,000	144,000	216,000
Lock and dam No. 1.	1926	do	20	220	(9)	(9)	(9)	0	0
Wilson	1925	do	137	4,862	805,000	1,259,400	0	335,200	436,000
Wheeler	1936	do	72	6,342	550,000	626,200	0	194,400	259,200
Guntersville	1939	do	94	3,979	470,000	289,700	813,900	72,900	97,200
Hales Bar	1914	do	112	2,315	500,000	(9)	(9)	51,100	99,700
Chickamauga	1940	do	129	5,800	470,000	491,800	2,635,800	81,000	108,000
Watts Bar	1942	do	112	2,960	585,000	480,200	1,173,000	150,000	150,000
Fort Loudoun	1943	do	122	4,190	410,000	575,000	1,783,000	128,000	128,000
Apalachia	1943	Hiwassee	150	1,308	135,000	448,500	0	75,000	75,000
Hiwassee	1940	do	307	1,287	[11] 109,000	793,000	14,200	57,600	115,200
Mission	1924	do	50	385	(9)	(9)	(9)	1,800	1,800
Chatuge	1942	do	144	[12] 2,850	[11] 13,870	21,900	2,347,400	0	(9)
Ocoee No. 1	1912	Ocoee	135	840	45,000	160,000	0	18,000	18,000
Ocoee No. 2	1913	do	30	450	(9)	0	0	19,900	19,900
Ocoee No. 3	1943	do	110	612	95,000	111,000	82,000	27,000	27,000
Blue Ridge	1931	Toccoa	167	1,000	55,000	(9)	1,500,000	20,000	20,000
Nottely	1942	Nottely	184	[15] 2,300	[11] 14,150	17,700	1,552,300	0	(9)
Norris	1936	Clinch	265	1,860	[11] 96,800	1,002,300	181,700	100,800	100,800
Calderwood [18]	1930	Little Tennessee.	230	897	260,000	(9)	0	121,500	121,500
Cheoah [18]	1919	do	230	770	200,000	(9)	0	76,000	106,000
Fontana	1944	do	480	2,365	[11] 134,160	2,812,000	306,000	135,000	202,500
Santeetlah [18]	1928	Cheoah	200	1,150	92,000	(9)	0	45,000	45,000
Nantahala [18]	1942	Nantahala	250	1,042	59,000	(9)	1,829,000	43,200	43,200
Glenville [18]	1941	Tuckasegee	150	900	56,000	(9)	458,000	21,600	21,600
Douglas	1943	French Broad	202	[19] 1,705	[11] 354,400	548,200	622,800	86,000	112,000
Marshall [20]	1910	do	(9)	(9)	(9)	(9)	(9)	3,000	3,000
Nolichucky	1913	Nolichucky	(9)	(9)	(9)	(9)	(9)	10,640	10,640
Waterville [20]	1930	Big Pigeon	200	870	60,000	124,200	0	108,000	108,000
Cherokee	1942	Holston	175	[21] 6,760	[11] 297,000	686,300	3,254,400	60,000	120,000
South Holston	(22)	South Fork, Holston.	290	1,550	105,000	90,500	5,958,000	35,000	35,000
Wilbur	1912	Watauga	(9)	363	25,000	(9)	(9)	3,700	(9)
Watauga	(22)	do	318	900	62,000	65,300	3,533,000	50,000	50,000
Great Falls [23]	1916	Caney Fork	92	800	150,000	(9)	(9)	31,860	31,860

[1] From deepest excavation on or near base line to roadway or deck.
[2] [illegible] el.
[illegible]
[illegible]
[illegible] to minimum expected pool level.
[6] At clearing line elevation.
[7] Except during drawdown in advance of floods at main-river plants.
[8] Head at maximum power storage level of tributary storage projects and average head at tributary run-of-river and main-river projects.
[9] No definite figure available.
[10] 2 lifts.
[11] [illegible] rge conduits.
[illegible], 1,480 feet additional.

to the Congress a unified plan for the coordination of such aims and outlining the following main elements:

1. Main river projects, comprising a low-head dam and major storage reservoir near the mouth of the Tennessee for regulating discharges into the Ohio River, and a series of low-head dams with limited reservoir storage for [illegible] crests. These developments further provide a 9-foot channel [illegible] and the necessary locks and power plants to utilize the 505-foot drop in elevation between Knoxville and Paducah.

in the Tennessee River Basin—June 1948

Lock		Reservoir data and operating levels								
Size (feet)	Maximum lift (feet)	Area at top of gates (acres)	Total volume below top of gates (acre-feet)	Useful [5] controlled storage (acre-feet)	Length[6] of shore line (miles)	Back-water length (miles)	Maximum controlled pool level (elevation)	Minimum [7] expected pool level (elevation)	Average tail-water level (elevation)	Head [8]
110 x 600	73	261, 000	6, 002, 600	4, 010, 800	2, 380	184. 3	375	354	310	47
110 x 600	63	46, 800	1, 091, 400	418, 400	496	52. 7	418	408	362	50
60 x 297	8	(9)	(9)	0	5	2. 6	(9)	(9)	(9)	(9)
{ 60 x 300 60 x 292	} [10] 92	15, 900	562, 500	52, 500	154	15. 5	507. 88	504. 5	414	92
60 x 360	52	68, 300	1, 150, 400	347, 500	1, 063	74. 1	556. 28	550	507	48
60 x 360	45	70, 700	1, 018, 700	162, 900	962	82. 1	595. 44	593	557	37
60 x 265	41	6, 750	154, 400	13, 100	100	39. 9	634	632	598	35
60 x 360	55	39, 400	705, 300	329, 400	810	58. 9	685. 44	675	635	45
60 x 360	70	43, 100	1, 132, 000	377, 600	783	72. 4	745	735	682	56
60 x 360	80	15, 500	386, 500	109, 300	368	55. 0	815	807	740	70
----------	--------	1, 123	58, 570	35, 730	31	9. 8	1, 280	1, 240	840	380
----------	--------	6, 280	438, 000	364, 700	180	22	1, 526. 5	1, 415	1, 275	254
----------	--------	(9)	283	(9)	(9)	1. 5	(9)	(9)	(9)	40
----------	--------	7, 150	247, 800	229, 300	132	13	1, 928	1, 860	1, 804	(9)
----------	--------	1, 900	91, 300	33, 100	18	7	837. 65	816. 9	724	113
----------	--------	(9)	(9)	(13)	(9)	0	1, 106. 2	(9)	[14] 843	252
----------	--------	606	14, 440	9, 370	24	7	1, 435	1, 413	[14] 1,119	300
----------	--------	3, 290	197, 500	183, 000	60	10	1, 690	1, 590	1, 543	147
----------	--------	4, 290	184, 400	184, 000	106	20	1, 780	1, 640	1, 611	(9)
----------	--------	40, 200	2, 567, 000	2, 281, 000	800	{ [16] 72 [17] 56	} 1, 034	930	826	194
----------	--------	541	41, 160	4, 090	(9)	8	1, 087. 5	1, 079. 5	[14] 872	213
----------	--------	632	35, 030	7, 260	(9)	10	1, 276. 6	1, 263. 6	1, 087	182
----------	--------	10, 670	1, 444, 300	1, 157, 300	274	29	1, 710	1, 525	1, 278	429
----------	--------	2, 881	158, 304	133, 334	85	(9)	1, 939. 92	1, 863. 0	[14] 1,275	665
----------	--------	1, 611	138, 577	126, 042	(9)	4. 6	3, 012. 16	2, 881. 0	[14] 2,007	975
----------	--------	1, 441	70, 829	67, 117	(9)	4. 5	3, 491. 75	3, 415. 0	2, 276. 6	1, 200
----------	--------	31, 600	1, 514, 100	1, 419, 700	556	43. 1	1, 002	920	873	129
----------	--------	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	34
----------	--------	930	16, 000	8, 050	(9)	(9)	(9)	(9)	(9)	68
----------	--------	340	25, 280	20, 500	(9)	5. 5	2, 258	2, 175	[14] 1,397	861
----------	--------	31, 100	1, 565, 400	1, 473, 100	463	59	1, 075	980	925	144
----------	--------	9, 100	783, 000	660, 000	241	25	1, 742	1, 616	1, 490	239
----------	--------	61	(9)	405	3	1. 5	1, 645. 3	1, 638. 3	1, 585	58
----------	--------	7, 100	677, 000	627, 000	117	17	1, 975	1, 815	1, 650	309
----------	--------	2, 270	54, 500	49, 400	120	22	804. 9	762	[14] 655	150

[13] Reservoir silted.

[16] Clinch.
[17] Powell.
[18] Property of Aluminum Co. of America; operation coordinated with TVA system.
[19] Saddle dams, 3,670 feet additional.
[20] Privately owned plant.
[21] Saddle dams, 1,770 feet additional.
[22] Under construction.
[23] Not in Tennessee Valley.

2. Tributary projects, comprising major storage developments to control the flow from the principal headwater tributaries of the Tennessee River. These projects afford means for substantial power generation and basic stream-flow regulation under multipurpose operation.

Table 1 lists the principal physical features of water control projects in the Tennessee Valley. Table 2 lists the installed and ultimate capacities of steam-generating plants in the TVA system October 1, 1945.

National defense

The defense efforts of the United States placed a tremendous responsibility on the Tennessee Valley for industrial expansion and production. In 1940 Congress, anticipating a demand for a large continuous power supply, had authorized TVA to initiate a supplementary power construction program including the Cherokee project on the Holston River, the Watts Bar Steam Plant, and the installation of three additional generating units in existing power plants. On May 27, 1941, the President recommended that Congress appropriate funds for further expansion of the TVA power system, and on July 16 construction of four dam and reservoir projects in the Hiwasse Basin and the installation of four additional generating units were authorized. [5]

TABLE 2.—*Steam plants in TVA system—generating capacity*

Project	Plant capacity Aug. 1, 1946	Ultimate plant capacity
	Kilowatts	*Kilowatts*
Nashville	48, 000	48, 000
Hales Bar	40, 000	40, 000
Parksville	13, 000	13, 000
Watts Bar	240, 000	240, 000
Wilson	64, 000	64, 000
Memphis (leased)	20, 000	20, 000
5 small plants	24, 350	24, 350
Total steam	449, 350	449, 350

Even while the second supplementary power program was under consideration, the need for additional energy to be available in 1943 became urgent. The Tennessee Valley and adjoining regions had made great strides in industrial development in the few years immediately preceding the outbreak of World War II, and had become a center for the production of light metals and chemicals, industries dependent upon the availability of vast supplies of electric power. An increased flow of material from the valley for the manufacture of aircraft and munitions was of vital importance to the Nation's armament program. The aluminum plants, chemical works, ordnance plants, and other defense industries in the area were scheduled to reach peak production in 1943. Military requirements on valley industry would find the region deficient in power if greater expansion of generating capacity were not immediately authorized. Among other projects suggested for possible development, a hydro project on the French Broad River was listed in a letter from TVA to the Office of Production Management on May 27, 1941. Later, the Douglas project was more specifically recommended to the Office of Production Management, although the problem of flooding valuable agricultural land was pointed out carefully. Contributing to the speed with which Douglas could be constructed and placed in operation were the immediate availability of a trained engineering and construction organization and heavy construction equipment from Cherokee, favorable site conditions, and sufficient volume of flow of the river to insure rapid filling of the reservoir. The major features of the Cherokee project

[5] 55 Stat. 597.

could be duplicated at Douglas, simplifying design and procurement, and a 30,000-kilowatt generating unit already ordered for Cherokee and scheduled for delivery in March 1942 could be installed in the Douglas powerhouse, making power available a year earlier than would otherwise be possible. There was no satisfactory substitute for the Douglas project in 1941.

On August 28, 1941, in a letter to the Bureau of the Budget, the Office of Production Management stated:

> In the Southeast, the programs for production of aluminum, ferrosilicons, and chemicals require immediate expansion of the power facilities of the Tennessee Valley Authority. Even after taking account of the recently authorized program to increase the system capacity of TVA, the power demands of defense industries already under construction in the area exceed by about 230,000 kilowatts of continuous power the capacity now available or authorized.

The immediate authorization of construction of Fontana and Douglas projects and installation of additional downstream generating units was strongly recommended.

The President on September 15, 1941, recommended that Congress approve a supplemental appropriation for construction of the projects proposed by the Office of Production Management.[6] Hearings were held by a subcommittee of the House Committee on Appropriations on October 1. Representatives of Office of Production Management and TVA testified as to the urgent need for beginning construction of the projects for which appropriation was requested.[7]

The subcommittee on October 8, 1941, reported the second supplemental national defense appropriation bill for 1942 without an estimate for the TVA, upon which action was postponed for 2 weeks.[8] The President in a letter to the chairman of the subcommittee expressed the hope that the committee would act promptly and favorably on the deferred estimate.[9]

On December 3, 1941, the House Committee on Appropriations reported the third supplemental national defense appropriation bill for 1942. Douglas Dam was eliminated because, in the opinion of the committee, it was controversial in nature, the need for the power it could produce was speculative, and an equal amount of power could possibly be obtained from other sources.[10] As H. R. 6159 the appropriation bill was approved by the House of Representatives on December 5, discussion of the TVA estimate was in the main concerned with the reasons for the elimination of funds for Douglas Dam.[11]

In testimony given on December 10, 1941, representatives of TVA and the Office of Production Management urged the Senate subcommittee to include an appropriation for the Douglas project in H. R. 6159 and the Under Secretary of War in a letter filed with the subcommittee recommended favorable consideration of the request.[12] However, funds for the Douglas project were not restored; instead funds were approved for alternative projects and the amended House Reso-

[6] H. Doc. 376, 77th Cong., 1st sess.

[7] Hearings before the subcommittee of the House Committee on Appropriations on the second supplemental national defense appropriations bill for 1942, pt. II, pp. 12–78.

[8] H. Rept. 1230, 77th Cong., 1st sess., to accompany H. R. 5788.

[9] Hearings before the subcommittee of the House Committee on Appropriations on the third supplemental national defense appropriation bill for 1942, pt. 1, p. 574.

[10] H. Rept. 1470, 77th Con., 1st sess., to accompany H. R. 6159, pp. 24–27.

[11] [illegible] Record, 87 : 9496, 87 : 9487–9488.

[12] [illegible] the subcommittee of the Senate Committee on Appropriations on H. R. 6159.

lution was so reported to the Senate.[13] Final efforts to secure inclusion of Douglas Dam in H. R. 6159 failed. The bill passed the Senate on December 12 [14] and on December 17 became Public Law 353.[15]

On January 15, the President for the third time requested Congress to appropriate funds for beginning construction of Douglas Dam.[16] In the 4 months that had elapsed since his first request, the defense requirements of the Nation had, with the dramatic bombing of Pearl Harbor, been transformed into the requirements of total war. The demand for a tremendously increased supply of electricity to become available in 1943 emphatically called for immediate construction of Douglas Dam.

The Douglas project was strongly recommended as an emergency power project because unique features of location and terrain made it the only project in the Tennessee Valley that could produce the block of power required in the short time left in which the energy must be made available. As had been explained to Congress, the great drainage area above the Douglas site would enable the reservoir to be filled quickly even in the driest years. Due to the similarity between the Douglas project and the Che[illegible] the Holston River some 20 miles away, many of the [illegible] of the latter could be duplicated at Douglas. Construction equipment in use at Cherokee could be transferred to Douglas for earlier operation. These factors meant that 90,000 kilowatts of continuous power could be made available by the construction of Douglas Dam in the critical summer of 1943, given early approval of the project. The TVA chief engineer stated "there is no substitute project or combination of projects that can produce the equivalent quantities of power in the same time" as the Douglas project.

Against these engineering determinations and the foreseen need for the potential energy from the Douglas project was the argument of economic dislocation of the area, a problem that became less complex as studies showed agricultural readjustments of the region could be accomplished without the difficulties first envisioned. With this argument was the proposal that additional power requirements be fulfilled through the construction of projects on the upper Holston and Cumberland Rivers and the expansion of steam generating facilities, a proposal which TVA engineering studies showed to be inadequate to meet the power demands within the required time limits.

TVA recommended the construction of the project as the only way to place the region in a position to produce the war materials demanded of it, but the recommendation did not mean that TVA proposed to ignore the needs of the affected communities. TVA in all its dam and reservoir projects had accepted and solved the complicated problems of readjustment, and although the Douglas problem was admittedly more difficult than earlier situations, there was no doubt but that with the cooperation of local citizens and institutions the required readjustment could be made.

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[13] S. Rept. No. 894, 77th Cong., 1st sess.
[14] Congressional Record, 87:9734.
[15] Ibid. 87:10100.
[16] H. Doc. No. 566, 77th Cong., 2d sess.

The Subcommittee of the House Committee on Appropriations did not receive testimony on the Douglas project at its hearings, January 20, 1942.[17] The record on Douglas was already extensive, having been considered by the subcommittee on two earlier occasions. On January 23, H. R. 6448, which contained estimates of over $12,000,000,000 for the War Department and $30,000,000 for Douglas Dam, was favorably reported.[18] The urgent need for power from Douglas Dam was described and the unusual merits of the project were extolled. "All of the factors fit admirably into war production requirements for speed, high output, and low cost."[19] The hazard of further delay was now clearly realized.

On the same day that it was reported, H. R. 6448 was debated and passed without a dissenting vote.[20] The same swift action characterized the progress of the bill in the Senate. On January 24 it was referred to the Committee on Appropriations.[21]

On January 27 hearings on the bill closed—H. R. 6448 was submitted to the Senate.[22] "Our country is now at war," the committee report stated, "and, notwithstanding previous opposition to this project, the committee feels that, inasmuch as the President has again requested the construction of this dam in the name of national defense, it should grant this repeated request of the President."[23] On January 28, the bill was passed by the Senate.[24] The bill was signed by the Speaker of the House and the Vice President on the following day.[25] On January 30, it was signed by the President as Public Law 422.[26] As finally approved the bill provided:

> For an additional amount for the Tennessee Valley Authority fund, fiscal year 1942, for (1) the construction of a hydroelectric project on the French Broad River near Dandridge, Tennessee, (2) the purchase or building of transmission facilities needed to connect this project to the existing transmission system of the Authority, and (3) the acquisition of land necessary for and the relocation of highways in connection with the accomplishment of the above project; $30,000,000, to be available for the administrative objects of expenditure and subject to the conditions specified under this heading in the Independent Offices Appropriations Act, 1942.

Construction of Douglas which began February 2, 1942, culminated with closure of the dam February 19, 1943. Its powerhouse was in operation 2 years before the war came to an end in Europe and made its full contribution to the successful war effort.

World War II led to three successive emergency programs under which 11 additional generating units were installed in main-river plants, Douglas and six other tributary dams were constructed and a large steam generating plant was built at Watts Bar. Table 3 shows projects constructed under the emergency program.

[17] Hearings before the subcommittee of the Committee on Appropriations, House of Representatives, 77th Cong., 2d sess., on H. R. 6448.
[18] Congressional Record, 88 : 590, 615.
[19] H. Rept. No. 1659, 77th Cong., 2d sess., p. 7.
[20] Congressional Record, 88 : 590–613.
[21] Ibid., 88 : 617.
[22] S. Rept. No. 994 on H. R. 6448, 77th Cong., 2d sess., and Congressional Record, 88 : 693.
[23] S. Rept. No. 994 on H. R. 6448, 77th Cong., 2d sess., p. 3.
[24] Congressional Record, 88 : 790.
[25] Ibid., 88 : 870, 894.
[26] Ibid., 88 : 911.

TABLE 3.—*World War II emergency program*

Program and project	Date authorized	Construction started	Closure	First use of units authorized under emergency program	Rated capacity
First emergency program:					
Cherokee	July 31, 1940	Aug. 1, 1940	Dec. 5, 1941	First unit Apr. 16, 1942	30,000
				Second unit June 17, 1942	30,000
Watts Bar steam	July 31, 1940	Aug. 8, 1940	----------	First unit Feb. 15, 1942	60,000
				Second unit Mar. 16, 1942	60,000
	Apr. 5, 1941	----------	----------	Third unit Feb. 8, 1943	60,000
Pickwick fourth unit	July 31, 1940	----------	----------	Aug. 12, 1942	36,000
Wilson:					
Eleventh unit	July 31, 1940	----------	----------	July 18, 1942	25,200
Twelfth unit	July 31, 1940	----------	----------	Aug. 31, 1942	25,200
Kentucky:					
First unit	Apr. 5, 1	----------	----------	Sept. 14, 1944	32,000
Second unit	Apr. 5, 1941	----------	----------	Nov. 18, 1944	32,000
Third unit	Apr. 5, 1941	----------	----------	Apr. 6, 1945	32,000
Fourth unit	Apr. 5, 1941	----------	----------	Dec. 23, 1945	32,000
Second emergency program:					
Apalachia	July 16, 1941	July 17, 1941	Feb. 14, 1943	First unit Sept. 22, 1943	37,500
				Second unit Nov. 17, 1943	37,500
Ocoee No. 3	July 16, 1941	July 17, 1941	Aug. 15, 1942	First unit Apr. 30, 1943	27,000
Nottely	July 16, 1941	July 17, 1941	Jan. 24, 1942	----------	----------
Chatuge	July 16, 1941	July 17, 1941	Feb. 12, 1942	----------	----------
Wilson:					
Thirteenth unit	July 16, 1941	----------	----------	Apr. 22, 1943	25,200
Fourteenth unit	July 16, 1941	----------	----------	Nov. 21, 1943	25,200
Watts Bar:					
4th unit	July 16, 1941	----------	----------	Mar. 12, 1944	30,000
Fifth unit	July 16, 1941	----------	----------	Apr. 24, 1944	30,000
Third emergency program:					
Douglas	Jan. 30, 1942	Feb. 2, 1942	Feb. 19, 1943	First unit Mar. 21, 1943	30,000
				Second unit Jan. 12, 1944	30,000
Fontana	Dec. 17, 1941	Jan. 1, 1942	Nov. 7, 1944	First unit Jan. 20, 1945	67,500
				Second unit Mar. 24, 1945	67,500
Watts Bar steam fourth unit.	Dec. 17, 1941	----------	----------	Apr. 8, 1945	60,000

BASIC DATA

The entire Tennessee River watershed covers an area of 40,910 square miles, and 4,541 square miles or approximately 11 percent is located above Douglas Dam in the French Broad Basin. This drainage area includes parts of Tennessee and North Carolina with the reservoir itself reaching into four Tennessee Counties: Sevier, Jefferson, Cocke, and Hamblen. The reservoir extends 43 miles upstream from the dam to a point just above the mouth of the Pigeon River near Newport, Tenn.

Topographic features

The topography in the upper Tennessee Valley is for the most part rugged with steep slopes. The French Broad Basin is a fan-shaped area having a width of about 30 miles above Douglas Dam site and about 90 miles at its southeast boundary. Douglas Reservoir lies in the rolling country between the Clinch Mountains on the northwest and the Smoky Mountains on the southeast. At the dam site the river flows in a general southwesterly direction, then turns to flow almost due south before turning in a great bend to flow generally in a westerly direction to join with the Holston near Knoxville to form the Tennessee River. The dam site is at a convergence in an otherwise broad valley. The stream bed is approximately 500 feet wide. The left bank rises rather steeply to about elevation 950 and on a more gentle slope to about elevation 1,060. The right bank shows

more evidence of a flood plain in the overbank area with the adjacent slope rising uniformly to a crest above elevation 1,100.

General geology

The rock formations in the vicinity of the site consist of gray dolomite and light-gray to blue limestone. Bedrock is exposed near the right abutment, and scattered rock outcrops are present in the left abutment from the flood plain to the crest elevation of the ridge. The Douglas area is on the northwest limit of a broad syncline which crosses the eastern end of the State of Tennessee from Sullivan County to Polk County. The dam is on the northwest limb of this fold and the dolomite beds dip southeasterly to pass under a thick mass of younger shales which extend below sea level before returning to the surface on the southeast limit of the syncline beyond the limits of the reservoir.

In an earlier period of its history the river was at the level of the upland terraces, about 80 to 100 feet above the present river. In cutting its way into the upland the river widened its valley through the soft shales and formed narrow channels across the belts of harder rocks. Douglas Dam is located in one of the narrow channels where the river leaves its broad valley through the shale belt and crosses a wide outcrop of Knox dolomite. This outcrop extends northeasterly along the western edge of the reservoir area to the broad upland area above Dandridge, and its surface contains many sinks and practically no surface streams. No mines or mineral deposits of appreciable value are located within the reservoir area.

Hydrology

Stream flow estimates for the French Broad River at the dam site are based on nearby gage records of the United States Geological Survey, those at Dandridge, with a drainage area of 4,446 square miles were available starting with October 1918. There were also available a fragmentary record over a period of 29 years for a gaging station near Newport and a continuous record since 1899 for the Knoxville gage on the Tennessee River with a drainage area of 8,934 square miles. The maximum known flood stage, 25.2 feet at Dandridge, occurred in March 1867 and again in February 1875. The minimum flow of record, about 370 cubic feet per second, occurred in September 1925. The average stream flow at the dam site during the typical 12-year period from October 1920 to September 1932, including both a critical dry and a very wet year, was about 6,700 cubic feet per second.

RESERVOIR PREPARATION

Land purchases and easements for Douglas Reservoir totaled 33,160 acres, of which 31,600 acres (including 3,170 acres in the original river bed) are below elevation 1002, top of spillway gates. Acreage purchased above 1002 was largely to avoid impractical severance of farm lands or expensive road relocations. Approximately 5,182 acres had to be cleared. Approximately 15,300 acres may be classed as bottom lands and included some of the most highly developed land purchased by TVA, while the remainder, some 17,860 acres, was cleared uplands and woodlands. Five hundred and twenty-five families with homes within the reservoir limits had to be moved. Dandridge, the only

incorporated town within the reservoir area and the county seat of Jefferson County, Tenn., required extensive protection from backwater of the reservoir. A protective dike constructed by TVA left the town practically undamaged. State and county roads required only minor adjustments on account of this dike and minor adjustments were also necessary to the existing street, water, and sewer systems.

United States Highway No. 25E was relocated for a distance of about 4 miles, and the highway bridge crossing the French Broad River on this route was raised. United States Highway No. 70 was raised about 0.4 of a mile, and the Swann Bridge over the French Broad River on this highway was raised. County road adjustments included two major bridges and many small culverts and side road approaches. The Southern Railway track extending for about 9 miles through the reservoir area, was elevated and the railroad bridge over the French Broad River at Leadvale raised.

Graves in flooded cemeteries were removed at the option of the nearest relative. Those for which no known relative could be found or which could not be identified were not disturbed. A total of 2,449 reinterments were made from 32 different cemeteries.

While several small rural communities were inundated, no highly developed residential areas were damaged to any extent.

INITIAL OPERATIONS

Filling of the reservoir began February 19, 1943, with the closure of the dam. The first power unit when into commercial operation March 21, 1943; the second January 12, 1944. For the first full year of operation, March 1943 through February 1944, the output totaled 214,973,000 kilowatt-hours. All through the critical war year of 1943, the first unit operated at maximum capacity, the output being continuously over the 30,000 kilowatt capacity for six consecutive months during this crucial period.

In conjunction with other TVA reservoirs, Douglas has been operated to advantage in the control of a number of floods. In January 1946 the crest of the fifth highest flood of record at Chattanooga was reduced approximately 10 feet with an estimated saving in flood damages at that point alone of $10,000,000. In January 1947 the sixth highest flood at Chattanooga occurred, and in February 1948 the seventh. These two floods were reduced by 12.7 and 10 feet with estimated resultant savings in flood damages of $7,500,000 and $6,000,000 respectively, to bring the total estimated savings from flood damages for these three major floods at Chattanooga alone to $23,500,000.

COST

The final cost of the Douglas project through June 30, 1947, totaled $41,800,000. This figure includes land, land rights, structures, improvements, and equipment; transmission plant consisting of the primary substation located at the power house site and constructed concurrently with the dam and powerhouse; and general plant comprising intersite communication equipment. A detail summary of costs is given in the cost chapter of this report.

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The bibliographies at the end of each chapter are not intended to include references to all phases of TVA activities; however, these titles will enable the reader to obtain specific information on the Douglas project, as well as general information on the unified development program. The Agricultural Index, Industrial Arts Index, Engineering Index, Reader's Guide to Periodical Literature, Public Affairs Information Service Bulletin and Education Index, available in many public and educational libraries, will aid the reader in making his own reading list or in exploring any of the special phases of the TVA program. For important newspaper articles the New York Times Index should be consulted.

The following indexes prepared by the TVA and available in many libraries throughout the United States and in some foreign countries will give the reader additional references to the TVA program: (1) Indexed Bibliography of the Tennessee Valley Authority; (2) Selected List of Books and Pamphlets on TVA; (3) Congressional Hearings, Reports, and Documents Relating to TVA.

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CHAPTER 2

PRELIMINARY INVESTIGATIONS

The French Broad River, with a total drainage area of 5,124 square miles, is the largest tributary of the Tennessee River. Any comprehensive plan for the multipurpose development of the Tennessee Valley necessarily involved consideration of a large storage project on this river, not only for controlling floods but also for regulating low-water flows. The relation of the French Broad drainage area to that of other watersheds in the upper Tennessee Valley is shown in figure 1.

The only large existing power development in the French Broad Basin was the high-head Waterville project of the Carolina Power & Light Co. completed in 1930 on the Big Pigeon River. The drainage area above Waterville is less than 9 percent of the entire French Broad watershed, and the reservoir has a useful storage of only 21,000 acre-feet. Excluding the drainage area above Waterville, Douglas Dam controls a drainage area which is substantially larger than that for any other dam which could be built on the tributaries of the Tennessee River; nor was it feasible to obtain the large capacity needed for flood storage and stream flow regulation at any other single site in the French Broad Basin.

From the mouth to the vicinity of Newport, Tenn., 78 miles upstream, the French Broad River flows through a wide fertile valley which is extensively cultivated. Between Newport and Asheville, for a distance of approximately 70 miles, the river runs through a gorge occupied by a main-line railroad and a primary United States highway. Above Asheville, the valley again widens out into a fertile, highly cultivated basin. The Nolichucky River, the principal tributary and flowing into the French Broad about 11.5 miles below Newport, has much the same type of highly developed fertile valley crossed by important railroads and highways. Except for the basin above Asheville, the entire upper watershed of the French Broad above Newport lies in a mountainous region.

Initial investigations

In House Document No. 328, 71st Congress, 2d session, the Corps of Engineers, United States Army, presented a plan for the comprehensive development of the water resources of the French Broad Basin. In general, the projects proposed lacked adequate storage for multipurpose use and involved extensive relocation of existing transportation routes. To avoid such difficulties as much as possible, relatively low dams and small reservoirs were proposed, and the water for power development was to be conveyed through long tunnels and pipe lines.

Intensive studies by the TVA, beginning in 1937, indicated that the so-called Douglas site, 32.3 miles above the mouth of the river,

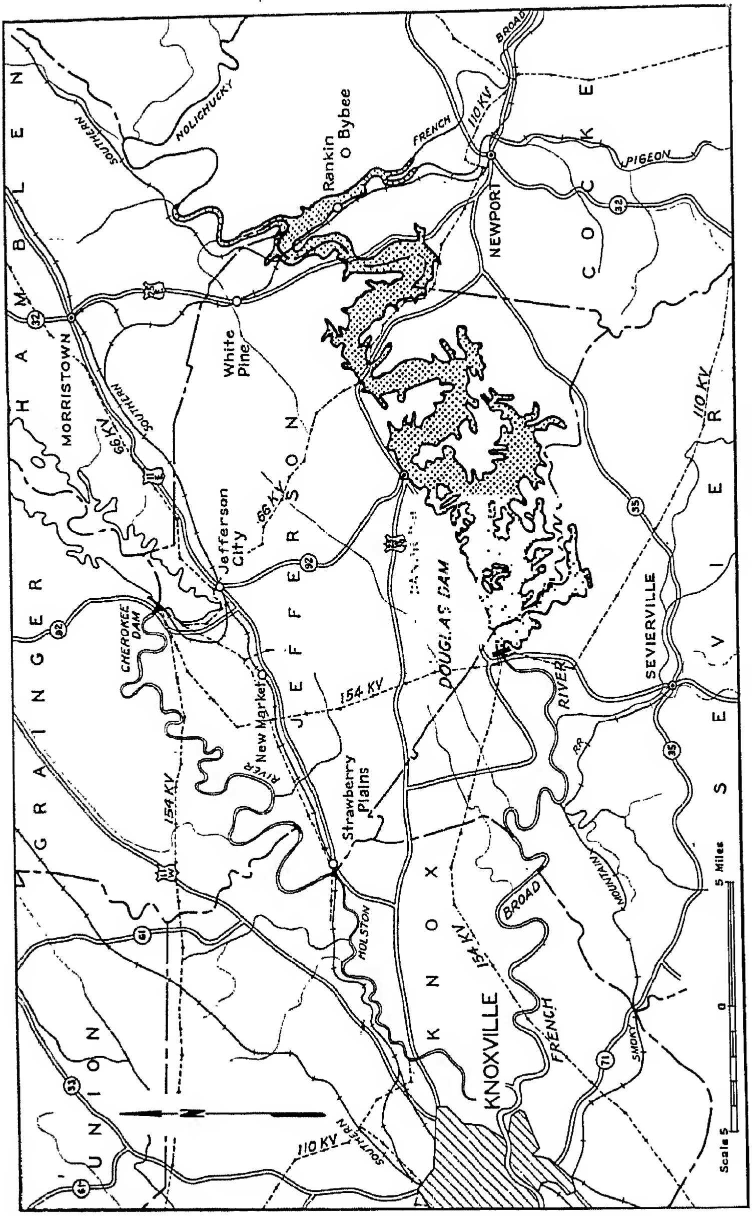


FIGURE 2.—*Douglas Reservoir and vicinity.*

was undoubtedly the most feasible and practicable site on the French Broad for multipurpose development and would afford a useful storage capacity for flood control and low-water regulation of approximately 1,300,000 acre-feet. Figure 2 is a map of the Douglas Reservoir and vicinity.

The difficulties to be encountered in acquiring the large acreage of highly cultivated bottom lands that would be inundated and in making extensive highway and utility adjustments indicated that, in normal times, the construction of Douglas Dam and Reservoir should reasonably be held in abeyance until other more feasible reservoir sites had been developed and necessary expansion of the TVA's multipurpose program could no longer be delayed. The economic effects of flooding the large area of agricultural land in the reservoir had been appraised, and the normal development of the Douglas site would have been postponed for several more years if Congress had not authorized the emergency power program recommended by the Office of Production Management for projects needed to meet the rapidly growing demands of power for national defense.

Congressional authorization of the first emergency power program (see table 3) had been passed in July 1940, and requests for a second emergency program submitted in July 1941 made it evident that actual development of the Douglas site would in all probability be called for very soon. Accordingly, exploratory drilling was started July 10, 1941, and was completed by November 22 of the same year.

Field investigations proved the feasibility of the site, and the project was recommended for the emergency program primarily on the premise that its construction would add a substantial block of dependable power to the TVA's system in the shortest possible time. The urgency of power requirements was held to overshadow all economic disadvantages which might result from the flooding of valuable truck farms serving two large canning industries.

The Douglas project was approved by Congress January 30, 1942, and authorized by the TVA Board of Directors February 2, 1942. Construction started immediately.

GEOLOGY

Douglas Dam and Reservoir are in the southeastern section of the Valley and Ridge province. This area has undergone practically the same geologic and physiographic development as have the other TVA reservoir areas in the upper Tennessee Valley. The dam is 10 miles west of the base of the Great Smoky Mountains. The French Broad River leaves the mountains about 20 miles above the upper end of the reservoir and flows westerly in a series of entrenched meanders across alternating belts of shale, dolomite, and limestone to join the Holston River and form the main Tennessee River about 5 miles above Knoxville.

In an earlier period of its history the river was at the level of the upland terraces, about 80 to 100 feet above the present river. In cutting its way into the upland, the river greatly widened its valley through the soft shales and formed narrow channels across the belts of harder rocks. Douglas Dam is located in one of the narrow channels where the river leaves its broad valley through the shale belt and crosses a wide outcrop of Knox dolomite. This outcrop extends northeasterly

along the western edge of the reservoir area to the broad upland area above Dandridge, and its surface contains many sinks and practically no surface streams.

The formations in the immediate vicinity are all of the Ordovician age. Figure 3 shows the geology at the dam site. The Knox dolomite is a thick-bedded, fine to coarse crystalline rock, having sandy and cherty layers throughout and beds of limestone along the upper part. In the immediate vicinity of the dam the Lenoir limestone overlies the Knox dolomite. It consists of a thin-bedded, slabby, somewhat shaly limestone with nodules of black chert in the lower beds and outcrops in a narrow belt parallel and adjacent to the larger dolomite formation. To the east is a wide maturely dissected belt of shale outcrop which consists of the Athens, Tellico, and Sevier formations located in the order named. These three shales form most of the reservoir bottom area because the main river and its tributaries were able to erode this shale more easily and extensively than the hard Knox dolomite.

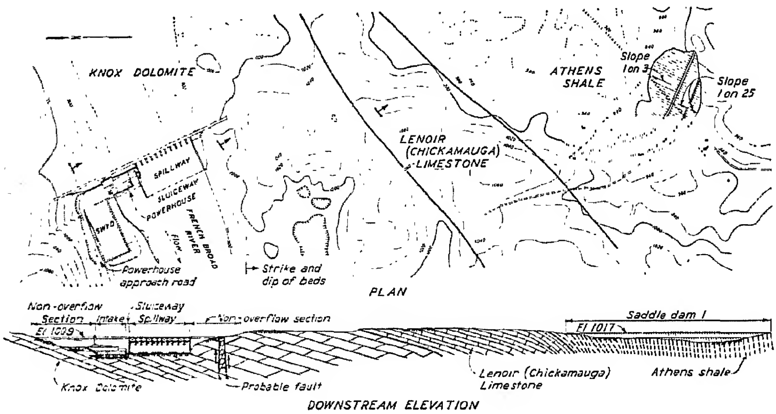


FIGURE 3.—*Geology of Douglas Dam site.*

Structurally, the Douglas area is on the northwest limb of a broad syncline which crosses the whole eastern end of the state from Sullivan County to Polk County. The dam is on the northwest limb of this fold, and the dolomite beds dip southeasterly to pass under a thick mass of younger shales which extend below sea level before returning to the surface on the southeast limb of the syncline beyond the limits of the reservoir. Crystalline rocks of the Blue Ridge thrust override the younger shales lying along the southeast limb of the syncline and compress the shale beds into many minor folds and faults which are difficult to trace at the surface but are frequently exposed in open cuts and drill holes.

Topography

The dolomite ridge forming the right bank at the dam site descends from a crest elevation of 1,100 feet or more down to around 895 feet along the edge of the flood plain. The slope of the ridge practically parallels the dip of the underlying strata. The total width between

abutments is 980 feet. The same width of flood plain, about 250 feet, exists along each side of the river. The vertical bluff at the end of the south flood plain is 75 feet high, and the gentle slope above rises to a maximum elevation of 1,060 feet between the dam and saddle dam No. 1. The dissected shale ridge forming the reservoir rim for about 4 miles above the dam has an average width of 1,000 feet at the upper pool level and a maximum elevation of about 1,240 feet. The crest of the ridge drops below 1,017, elevation of the top of embankment, at eight gaps, each of which was closed by a saddle dam.

Removal of overburden was a comparatively unimportant item in dam construction although requiring excavation to a considerable depth in the south abutment cave and at other spots. In general, the depth of overburden averaged about 16.5 feet over the entire site.

The most serious difficulty anticipated in the construction of a dam at the Douglas site was the probability of extensive rim leakage as evidenced not only by numerous sinkholes near and immediately south of the left abutment but also by the presence of many cavities and weathered seams along bedding planes in the foundation rock. It was expected that considerable grouting would be required under the left abutment and to a lesser extent along the weathered zone in the river bed and under the right abutment.

Rock formation

The rock under both the dam and powerhouse belongs to the upper portion of the Knox dolomite, which has a total stratigraphic thickness of 525 feet and represents 7 rock types, the youngest of which goes down about 200 feet below the top of the rock formation.

Explorations

A preliminary examination of the outcrops and overburden by means of auger borings was made in 1938 and 1939 along a line approximately 650 feet downstream from the final axis. Between July and November 1941, 80 diamond drill holes and 4 large-diameter calyx holes were drilled. The principal foundiation features disclosed by such explorations were:

1. A large partly clay-filled bedding plane cave in the south abutment.
2. A smaller and more open bedding plane cave in the north abutment. Dye tests throughout the drilling indicated interconnection between the cavities in most of the holes.
3. A number of large bedding plane and joint cavities existed in the river channel and flood plain, especially in the upper 30 feet of bedrock. The deepest cavity went down about 80 feet below river level, and the drill water was lost in every hole.
4. Reasonably watertight shale underneath the shallow weathered surface zone was found at all saddle dam sites.
5. Unusual rock types bounded by steep faults were found in the south abutment area. The larger cavities found went as deep as elevation 820, or about 50 feet below the bed of the river and were presumably related to faulting.

At the dam site the strike is north 60 degrees east, or nearly parallel to the course of the river, and the dip is 10 to 25 degrees southeast. It was concluded from the preliminary explorations that the foundation rock at the Douglas Dam site would be satisfactory for the structure of the height proposed; and foundation conditions, in general, were comparable with those previously encountered at other TVA dams.

Extensive explorations of local spots were conducted during the entire construction period, using diamond, calyx, and wagon drills to determine the size and extent of cavities and the limits of weathered rock. In general, while many bad spots were encountered, the conditions actually exposed in the excavations were largely as anticipated in preliminary studies.

HYDROLOGY AND METEOROLOGY

The French Broad River Basin includes areas of widely different hydrological characteristics. Summer storms over the mountainous area are frequently violent and the heavy rains cause extensive damage, as shown by the storms of July 1916, August 1928, and August 1940. Destructive floods, however, are not confined to the summer season, the two largest floods in the vicinity of Douglas Dam having occurred in February 1875 and March 1867. The melting of snow accumulated in the mountain ridges may also contribute to winter and spring floods on the French Broad River.

The highest rates of precipitation are from West Indian hurricanes which occur in the summer and fall months and occasionally cover the eastern portion of the French Broad Basin. These storms sweeping inland from the ocean drop a considerable portion of their moisture along the Blue Ridge and Unaka Mountains. One of the storms of this type was that of July 1916, which produced the highest rate of rainfall known at that time in the country. At Altapass, about 18 miles northeast of the French Broad Basin, a rainfall of 22.22 inches was reported in a 24-hour period. These intense storms are confined to the eastern portion of the French Broad Basin and so far have not penetrated deeply into the Holston, French Broad, and Little Tennessee Basins.

Storms traveling across the Tennessee Valley from the southwest during the winter and spring are more frequent, as indicated by the flood occurrences on figure 12. Although precipitation from these storms is not as intense as from the summer storms, larger areas are covered and, with a higher percentage of run-off, more widespread floods results. Hence, winter and spring floods on the Tennessee River and on the lower reaches of the major tributaries are more severe than floods produced by summer storms over the mountainous regions.

Records of past storms and floods indicate that the summer storms will never reach far enough over the basin divide to cause intense precipitation over the entire drainage area of a major tributary. Nevertheless, it is considered desirable to provide sufficient spillway capacity at Douglas Dam to pass the maximum probable flood with the reservoir filled to normal capacity prior to the storm, even though a substantial volume of flood control storage may generally be available.

The mean annual rainfall over the area above Douglas Dam varies from 40 inches at Asheville to about 85 inches in the mountainous regions and averages about 47 inches over the entire area. The mean annual rainfall in the upper Tennessee River Basin is shown in figure 4.

The drainage area above Douglas Dam is 4,541 square miles. Stream flow records for the French Broad River at Dandridge (drainage

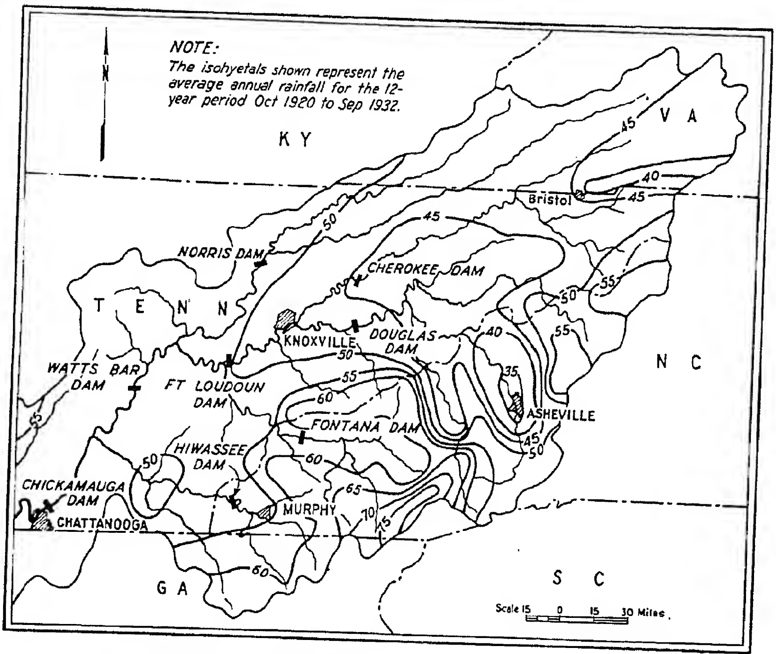


FIGURE 4.—*Mean annual rainfall in the upper Tennessee River Basin.*

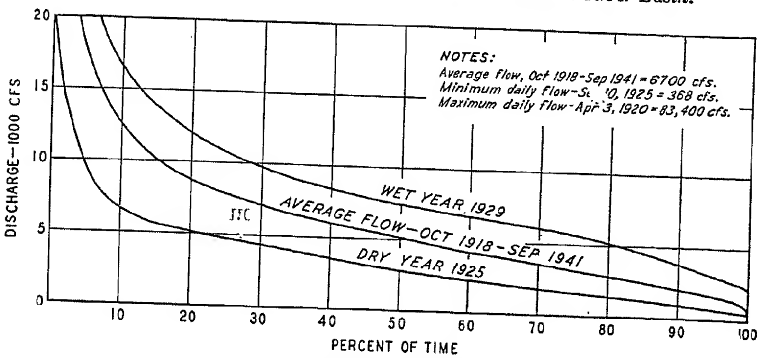


FIGURE 5.—*Duration of flow of the French Broad River at Dandridge, Tenn.*

area 4,446 square miles) were available since October 1918 with additional gage height records available since December 1904. There was also available an incomplete record for a period of 29 years for a gaging station near Newport (drainage area 1,858 square miles), and for Knoxville (drainage area 8,934 square miles) a continuous record of stream flow since January 1899 was available.

The maximum known flood stage, 25.2 feet at Dandridge, occurred on March 7, 1867, and again on February 25, 1875. The correspond-

ing discharge was 150,000 cubic feet per second (see fig. 12). The minimum daily flow of record, about 370 cubic feet per second at the dam, occurred in September 1925, and the average stream flow for the period from 1918 to 1943 was 6,700 cubic feet per second. Figure

TABLE 4.—*Natural flow, by weeks, of the French Broad River at Douglas Dam Site*

MEAN WEEKLY DISCHARGE IN CUBIC FEET PER SECOND

Week ending	Week	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913
Jan. 7	1	5,600	1,600	4,000	10,000	12,800	16,300	10,500	3,400	17,600	8,600	6,200
14	2	5,700	1,400	10,900	7,800	7,000	17,900	8,600	7,000	6,500	5,500	7,800
21	3	4,400	2,600	9,300	9,000	5,300	13,800	12,800	4,000	4,800	4,100	7,200
28	4	4,000	4,700	3,300	24,000	5,400	6,900	7,600	7,800	4,500	4,800	17,100
Feb. 4	5	4,700	2,500	2,700	14,300	4,900	7,000	6,400	5,000	6,000	9,500	15,700
11	6	17,600	4,000	11,800	7,700	8,000	6,500	10,400	5,000	19,100	5,900	7,300
18	7	20,900	3,400	11,900	6,400	4,800	21,000	17,500	5,100	12,000	5,500	10,100
25	8	17,800	6,100	18,700	6,300	3,900	11,500	17,900	11,600	5,600	12,300	5,900
Mar. 4	9	20,700	9,100	9,500	6,600	10,400	8,100	15,500	11,600	5,400	15,400	15,500
11	10	20,200	11,600	12,200	8,000	9,700	10,000	16,600	7,500	18,200	11,600	7,100
18	11	16,100	8,300	11,000	10,700	12,500	13,100	19,800	5,400	9,000	20,200	29,400
25	12	25,200	14,900	6,400	10,200	7,200	16,000	14,300	3,600	6,000	12,700	15,300
Apr. 1	13	23,200	15,100	4,900	9,600	5,700	13,300	23,300	3,300	7,200	22,400	29,800
8	14	22,200	6,100	4,900	8,600	6,400	9,000	11,100	3,100	21,600	27,400	10,300
15	15	39,400	5,400	10,300	9,300	8,000	6,500	9,000	3,100	17,400	9,400	8,900
22	16	22,800	4,500	6,300	11,100	6,900	7,500	9,400	5,300	16,300	9,000	12,800
29	17	14,000	4,200	5,100	6,000	9,600	12,500	9,100	4,500	9,000	17,500	6,700
May 6	18	10,000	7,000	5,900	6,300	8,300	7,500	19,600	3,700	11,700	21,000	6,000
13	19	7,100	8,100	9,700	9,900	11,300	7,700	15,200	8,000	6,000	12,600	5,600
20	20	5,800	5,100	14,700	4,700	6,300	5,100	7,800	5,600	5,200	8,300	5,300
27	21	4,700	3,200	8,500	3,600	4,200	6,400	18,400	7,900	4,200	15,700	16,500
June 3	22	7,600	3,600	6,600	5,500	4,900	5,200	8,800	6,900	3,700	7,700	13,000
10	23	13,000	4,200	3,700	5,000	13,600	4,500	22,800	5,900	3,400	5,900	10,700
17	24	9,600	2,500	3,300	9,600	11,000	4,500	14,700	7,200	3,700	4,500	7,300
24	25	5,600	2,500	8,300	8,400	6,200	3,200	11,100	6,200	3,000	4,300	4,700
July 1	26	5,000	3,500	6,000	6,900	6,600	3,300	10,000	5,000	3,800	7,200	4,300
8	27	4,800	3,600	5,600	4,700	4,800	5,100	11,800	7,200	2,400	9,400	4,600
15	28	5,200	3,300	15,000	5,300	6,000	7,900	15,900	11,600	3,600	7,500	3,200
22	29	5,000	2,000	11,000	12,100	6,400	3,400	8,700	6,800	3,700	6,300	2,700
29	30	2,800	2,900	6,300	8,900	3,400	2,400	6,200	4,000	3,300	7,400	2,900
Aug. 5	31	4,200	2,600	4,600	8,100	5,600	3,700	7,200	8,200	2,000	5,700	3,500
12	32	3,900	3,600	6,900	6,300	3,800	6,000	5,900	7,200	3,600	4,200	3,000
19	33	4,200	3,900	13,800	7,600	3,100	2,700	12,400	3,900	2,700	4,000	3,200
26	34	3,300	3,400	7,000	8,700	4,500	6,700	5,400	3,900	1,400	4,400	2,100
Sept. 2	35	2,100	2,800	4,900	16,300	3,300	10,000	3,900	11,000	2,700	3,000	2,100
9	36	2,000	2,600	4,100	13,100	2,300	4,700	3,600	12,200	3,500	2,400	2,100
16	37	1,700	1,700	2,800	7,500	3,500	2,900	3,500	6,200	1,100	1,800	1,500
23	38	1,900	1,300	2,300	14,700	2,600	1,400	4,400	3,900	1,700	3,000	3,000
30	39	1,500	1,100	1,900	10,000	10,300	1,700	6,900	3,600	3,500	6,000	3,300
Oct. 7	40	800	1,100	1,900	19,600	4,100	2,100	3,800	3,400	2,700	3,100	2,200
14	41	1,900	1,000	2,900	11,300	3,100	3,800	3,600	4,600	3,400	2,100	1,700
21	42	1,600	1,000	2,300	6,900	2,400	2,500	5,300	2,600	6,600	2,900	1,400
28	43	1,500	1,000	2,200	9,300	2,100	7,500	3,500	2,500	4,300	2,400	4,100
Nov. 4	44	1,300	1,100	2,200	5,400	2,500	10,900	2,900	2,100	3,200	1,900	3,000
11	45	1,900	1,500	1,900	4,700	2,900	4,600	2,500	1,900	3,900	3,700	2,200
18	46	2,200	1,600	1,800	4,600	5,500	5,100	2,400	1,400	5,100	3,200	2,900
25	47	3,700	1,600	2,100	28,500	7,200	4,300	2,100	1,000	4,700	2,200	2,800
Dec. 2	48	1,600	1,600	1,900	7,800	8,100	2,600	1,900	2,000	4,200	1,500	1,600
9	49	1,400	4,000	8,500	5,900	3,700	10,200	2,300	9,000	3,100	4,800	3,300
16	50	1,400	2,800	8,600	5,700	6,200	9,800	5,800	4,200	2,600	3,200	3,000
23	51	1,800	1,700	5,700	7,700	5,600	6,000	4,700	2,900	5,300	1,800	2,100
31	52	2,600	4,500	8,000	12,200	10,400	11,200	2,300	3,800	12,800	3,000	3,600
Max. Daily cfs		-										
Min. Daily cfs												
Mean for year cfs		8,050	3,950	6,660	9,210	6,250	7,390	9,350	5,450	6,320	7,320	6,880

NOTE.—Flow at Douglas computed from USGS streamflow records at Knoxville, Rogersville, and Dandridge as follows: Jan. 1, 1903 to Sept. 30, 1918, Douglas=0.77 (Knoxville—Rogersville) Oct. 1, 1918 to Dec. 31, 1920, Douglas=1.021 x Dandridge.

5 shows the average duration of flow at Dandridge for the 23-year period from October 1918 to September 1941. Mean weekly flows shown in table 4 have been computed from available records. Figure 6 gives the tailwater rating curve at Douglas Dam.

TABLE 4.—*Natural flow, by weeks, of the French Broad River at Douglas Dam site*—Continued

MEAN WEEKLY DISCHARGE IN CUBIC FEET PER SECOND

Week ending	Week	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
Jan. 7	1	4,400	9,300	20,200	24,700	1,800	24,700	3,040	6,380	4,380	11,100	11,200
14	2	3,500	13,600	21,200	10,200	9,100	9,120	3,640	10,300	5,830	5,250	13,800
21	3	3,500	14,400	11,300	8,800	22,700	9,820	4,670	12,700	15,400	5,170	16,500
28	4	2,800	12,600	13,600	12,300	13,000	17,400	12,100	7,410	22,200	8,590	8,570
Feb. 4	5	4,200	16,800	18,400	16,400	42,000	10,100	7,860	9,670	6,710	22,000	6,560
11	6	7,200	14,900	15,700	6,000	10,100	6,600	12,800	22,200	7,960	17,600	7,490
18	7	5,400	8,300	8,600	5,200	8,000	7,650	5,880	19,000	21,800	18,100	6,090
25	8	5,900	7,500	6,500	20,100	10,700	10,900	9,560	12,400	10,200	6,840	12,300
Mar. 4	9	5,700	8,200	13,600	27,800	6,700	12,600	7,720	7,500	13,300	5,310	11,600
11	10	5,100	7,700	14,200	43,000	5,300	18,200	6,730	5,700	16,400	16,500	19,200
18	11	10,700	5,700	7,800	23,000	5,300	11,600	23,700	5,180	22,800	22,600	8,210
25	12	7,000	6,200	5,800	24,100	4,900	9,100	20,300	5,590	10,900	18,100	10,500
Apr. 1	13	6,000	4,900	8,700	27,300	9,900	8,940	14,700	6,600	14,600	8,620	9,140
8	14	9,400	4,800	7,500	14,800	5,200	7,400	45,700	6,560	13,900	6,760	8,650
15	15	7,000	6,200	8,400	12,700	9,300	7,120	12,800	4,440	9,770	7,390	9,630
22	16	16,500	4,500	5,900	7,700	8,700	8,350	7,780	14,200	12,200	7,950	14,700
29	17	8,200	4,100	4,500	5,200	6,900	6,040	8,940	7,920	10,500	6,290	8,520
May 6	18	5,200	5,300	3,900	8,900	5,100	8,340	7,260	8,490	16,000	7,450	9,740
13	19	5,200	8,500	4,100	6,200	6,000	7,400	6,580	9,180	12,500	10,100	9,460
20	20	3,800	5,300	3,200	5,400	7,600	6,330	5,290	7,090	9,610	11,200	9,120
27	21	3,200	4,500	6,300	4,700	5,700	6,480	5,090	9,420	9,210	13,200	6,190
June 3	22	2,800	9,000	7,500	3,700	5,600	5,680	4,750	6,370	7,090	17,700	9,100
10	23	3,100	6,700	5,900	3,800	6,300	4,130	8,440	4,830	9,610	9,430	5,660
17	24	2,900	5,600	7,500	4,500	4,700	3,140	4,380	5,610	7,580	7,280	9,370
24	25	4,600	5,600	7,300	4,700	11,800	3,960	7,150	6,340	7,400	5,690	5,050
July 1	26	2,500	4,500	5,200	3,700	7,300	13,100	5,000	5,930	5,250	7,650	4,190
8	27	2,500	12,000	4,600	3,300	5,600	3,980	4,890	4,280	8,650	5,580	7,410
15	28	2,300	7,400	22,400	4,700	4,600	3,440	3,980	4,840	9,480	5,700	9,840
22	29	3,500	5,700	42,000	11,300	3,000	6,760	6,840	14,100	9,430	8,390	6,830
29	30	2,100	4,800	16,900	8,000	4,300	5,320	4,500	9,380	7,710	4,210	4,590
Aug. 5	31	2,900	3,600	9,200	6,300	5,900	3,780	3,290	11,500	5,320	5,180	3,500
12	32	1,600	3,000	11,400	4,800	3,800	3,320	8,410	7,660	4,350	7,240	4,670
19	33	3,400	3,900	8,300	3,700	4,000	4,560	13,500	14,400	3,720	5,370	3,960
26	34	1,500	4,900	6,000	4,200	4,600	2,990	10,600	9,040	3,580	5,150	2,720
Sept. 2	35	3,400	4,300	3,700	3,700	2,600	2,230	9,930	5,800	3,470	3,600	2,950
9	36	1,700	5,800	3,700	5,700	3,700	2,300	5,900	4,040	3,120	3,280	2,540
16	37	1,600	4,200	3,700	2,700	4,200	1,650	8,950	3,900	2,470	3,170	2,120
23	38	2,000	3,200	3,400	1,800	3,300	1,190	6,380	3,060	2,020	2,960	3,870
30	39	1,700	2,600	2,800	3,000	3,100	1,750	4,690	3,560	2,320	3,650	7,660
Oct. 7	40	1,600	7,500	3,500	2,400	1,490	1,310	3,970	3,990	2,020	2,240	8,110
14	41	1,700	4,900	2,100	1,800	1,070	1,750	2,550	2,810	3,450	2,050	3,340
21	42	12,400	4,000	3,400	2,200	1,100	2,960	2,270	2,340	2,380	2,050	2,510
28	43	3,500	4,600	4,000	3,700	15,400	3,760	2,140	2,180	2,280	2,440	2,630
Nov. 4	44	2,100	3,100	2,700	2,600	35,300	2,380	2,680	4,660	2,180	2,220	2,910
11	45	1,900	2,600	2,400	2,300	6,360	1,800	2,160	3,700	2,060	3,250	2,370
18	46	3,200	4,800	2,600	2,100	4,710	2,780	4,310	4,430	2,100	2,380	2,390
25	47	3,500	7,100	2,400	1,800	6,360	2,020	4,530	5,350	2,080	2,300	3,150
Dec. 2	48	6,100	4,400	3,300	2,000	5,620	1,940	3,990	7,110	1,720	3,250	2,450
9	49	22,300	3,600	3,500	2,200	4,450	2,790	4,580	7,510	4,570	5,230	8,450
16	50	6,400	3,500	3,700	1,700	5,540	14,900	16,100	4,420	8,190	4,510	10,700
23	51	5,100	23,000	2,900	2,300	18,600	5,890	9,850	5,130	15,800	5,140	4,310
31	52	22,500	17,400	8,300	2,400	18,600	3,730	10,700	5,470	5,250	5,800	4,950
Max. daily cfs									59,600	57,200	38,100	38,100
Min. daily cfs									2,020	1,230	1,810	1,810
Mean for year cfs		5,210	6,960	8,200	8,210	8,050	6,440	8,150	7,340	8,130	7,500	7,150

TABLE 4.—*Natural flow, by weeks, of the French Broad River at Douglas Dam site*—Continued

MEAN WEEKLY DISCHARGE IN CUBIC FEET PER SECOND

Week ending	Week	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Jan. 7	1	11,300	2,990	10,000	8,780	4,950	7,610	5,210	9,770	15,200	4,000	8,700
14	2	*11,400*	*3,020*	*5,740*	*6,750*	*7,170*	*6,030*	*6,850*	*11,100*	*12,200*	*6,000*	*18,800*
21	3	11,000	10,200	5,700	6,280	6,730	6,210	4,780	8,000	7,900	3,600	8,300
28	4	8,870	7,080	5,740	6,170	9,590	6,580	4,200	6,090	12,000	2,300	11,900
Feb. 4	5	5,710	8,510	10,400	6,400	6,500	6,000	3,270	23,200	9,600	2,300	6,400
11	6	4,890	8,050	11,900	8,430	9,060	9,800	3,330	16,800	15,100	2,600	5,400
18	7	8,660	6,580	10,900	6,220	7,440	8,450	4,920	16,300	24,400	2,200	10,600
25	8	6,620	9,980	20,300	5,600	9,200	6,720	4,570	11,700	14,400	2,300	7,200
Mar. 4	9	5,720	7,700	12,800	5,160	22,800	6,530	5,350	7,420	8,600	18,700	9,200
11	10	5,010	7,880	19,000	6,680	23,000	11,000	4,750	11,100	7,300	18,500	10,000
18	11	4,220	7,490	14,200	9,000	22,700	8,920	4,070	6,060	7,200	6,200	19,700
25	12	5,710	8,190	8,600	10,000	21,200	13,200	3,790	9,310	11,900	8,900	17,200
Apr. 1	13	4,520	6,960	6,710	10,800	15,600	6,670	6,410	11,100	6,900	16,400	28,200
8	14	3,840	5,960	6,800	8,510	9,350	8,450	21,100	10,100	6,400	7,000	17,000
15	15	3,840	13,600	7,350	13,300	7,800	7,180	11,600	9,480	6,100	11,000	11,800
22	16	3,240	7,540	7,180	9,130	7,300	5,730	6,990	6,290	12,500	9,300	10,400
29	17	4,070	5,160	11,400	12,700	8,160	4,880	13,800	8,150	7,400	7,200	11,600
May 6	18	6,300	3,870	6,130	12,300	12,606	4,110	6,780	14,400	7,800	5,000	7,100
13	19	3,910	3,520	4,550	18,900	16,800	5,100	7,530	7,150	16,500	4,200	6,600
20	20	4,570	5,290	3,760	10,000	15,200	8,090	5,830	5,780	8,800	4,400	8,900
27	21	3,810	3,480	3,700	14,600	15,500	6,420	5,980	5,590	6,400	4,000	7,000
June 3	22	2,530	2,650	15,400	16,300	12,000	4,170	6,450	4,640	6,100	4,300	5,100
10	23	2,200	2,370	11,600	10,500	8,690	3,650	4,690	3,750	3,900	6,200	4,900
17	24	2,050	2,780	7,570	10,600	7,940	3,140	3,980	5,850	3,900	7,500	4,300
24	25	2,310	2,760	9,120	8,100	5,950	3,020	3,130	5,280	2,800	6,600	4,100
July 1	26	2,530	2,390	4,700	18,100	8,000	2,620	2,740	4,300	4,100	4,500	3,600
8	27	2,580	2,430	4,000	12,800	8,280	2,250	3,300	5,260	3,200	4,500	4,200
15	28	2,670	2,280	3,830	10,400	6,770	2,100	3,010	4,230	3,300	5,600	4,000
22	29	1,770	1,730	5,550	6,660	6,140	2,640	4,890	3,440	3,500	7,900	4,100
29	30	1,450	1,920	4,330	6,900	5,120	2,420	5,610	2,640	4,100	4,200	6,200
Aug. 5	31	1,240	4,780	3,660	7,090	5,700	1,890	3,890	2,870	4,500	5,000	4,400
12	32	1,130	3,240	4,220	7,120	3,760	1,620	5,340	4,020	3,300	3,600	3,700
19	33	1,040	2,480	4,520	25,900	4,490	1,860	3,930	3,150	3,600	6,400	3,300
26	34	881	5,570	3,070	12,200	2,850	2,790	7,750	2,810	3,500	4,700	8,100
Sept. 2	35	702	4,690	3,020	9,840	2,640	1,540	4,200	2,120	4,500	4,200	4,400
9	36	640	2,720	3,310	25,000	2,820	1,260	7,150	1,840	7,000	3,300	5,200
16	37	1,150	3,220	2,610	9,610	3,570	3,020	2,930	1,470	5,600	2,800	4,200
23	38	1,050	2,140	2,300	9,260	5,120	3,280	2,820	1,360	3,600	3,400	3,500
30	39	1,220	2,160	1,870	6,120	10,600	3,060	1,770	2,470	2,800	3,600	2,100
Oct. 7	40	1,310	2,400	1,680	5,780	17,300	2,080	1,330	3,280	2,200	5,900	1,900
14	41	1,290	2,010	3,010	5,360	6,240	1,740	1,350	3,420	1,800	8,300	1,700
21	42	3,180	2,400	3,260	8,420	4,470	1,510	1,450	13,700	2,800	4,800	1,700
28	43	2,740	1,950	2,120	9,850	13,900	1,780	1,410	6,070	1,700	3,600	2,000
Nov. 4	44	2,200	2,000	1,910	5,820	7,250	1,840	1,810	9,670	2,000	4,600	3,200
11	45	3,200	2,710	2,360	5,160	8,900	1,900	1,440	6,550	2,500	5,400	2,400
18	46	5,530	8,900	3,180	4,500	11,800	3,320	1,440	5,630	2,100	3,900	10,500
25	47	2,780	6,920	6,410	5,450	10,700	4,600	1,710	6,660	2,200	4,400	4,800
Dec. 2	48	2,800	7,290	3,210	4,590	7,810	3,240	1,920	6,390	1,800	8,400	4,000
9	49	2,450	4,330	14,300	4,300	7,120	4,410	3,970	4,870	2,200	8,300	3,200
16	50	2,220	11,400	8,220	3,560	6,040	4,040	9,320	14,100	2,700	5,200	3,600
23	51	2,840	8,420	13,000	4,650	6,810	3,430	7,300	11,800	2,200	4,900	3,700
31	52	*2,700*	*23,500*	*5,900*	*3,510*	*7,770*	*3,810*	*7,000*	*31,000*	*2,600*	*5,200*	*3,100*
Max. daily cfs		20,100	36,400	50,200	70,500	45,200	21,600	35,000	57,500	48,500	46,000	61,600
Min. daily cfs		368	1,310	1,470	3,160	2,240	812	1,130	1,020	1,390	1,670	1,230
Mean for year cfs		3,690	5,380	6,860	9,190	9,330	4,580	5,000	7,690	6,280	5,900	7,060

TABLE 4.—*Natural flow, by weeks, of the French Broad River at Douglas Dam site*—Continued

MEAN WEEKLY DISCHARGE IN CUBIC FEET PER SECOND

Week ending	Week	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Jan. 7	1	13,100	32,200	8,300	4,950	1,630	6,000	3,980	17,000	6,990	13,000
14	2	18,900	15,100	5,800	5,060	1,790	3,930	2,420	6,710	3,500	8,260
21	3	29,600	25,900	4,800	5,510	3,420	3,860	3,310	9,940	5,250	6,400
28	4	13,200	19,200	9,000	5,320	2,050	4,280	3,220	10,900	3,050	5,590
Feb. 4	5	10,200	14,700	7,600	14,200	2,180	3,710	3,670	16,100	2,760	3,740
11	6	19,100	16,100	5,700	19,900	2,910	3,180	6,290	21,600	6,760	4,360
18	7	15,700	12,000	9,700	26,000	4,130	3,190	6,720	10,000	16,300	19,300
25	8	11,200	10,400	8,100	11,300	7,290	2,650	7,640	7,600	16,300	18,000
Mar. 4	9	8,400	9,100	8,600	13,200	6,630	2,660	4,490	6,150	17,400	12,000
11	10	7,800	9,000	16,390	18,800	5,620	6,920	13,300	5,530	11,000	11,500
18	11	7,600	7,500	12,200	9,770	6,690	7,140	13,100	10,200	7,900	6,060
25	12	23,100	7,100	9,800	6,810	5,960	4,230	10,100	21,600	16,100	7,230
Apr. 1	13	37,200	6,200	8,000	6,410	5,810	6,520	6,430	12,300	24,200	14,000
8	14	38,200	6,300	6,900	7,530	6,290	6,840	4,780	6,890	10,400	7,970
15	15	20,600	7,500	7,000	6,730	5,720	5,050	4,350	7,000	12,200	5,000
22	16	10,600	6,500	6,900	6,090	11,700	3,880	3,570	10,500	9,800	9,190
29	17	8,400	8,200	7,200	6,190	9,980	5,850	3,240	9,010	8,870	8,710
May 6	18	6,900	7,500	5,000	5,110	4,910	3,830	3,380	5,970	6,510	8,260
13	19	5,800	6,200	4,160	4,520	4,170	3,280	3,000	6,640	6,040	8,120
20	20	5,600	6,200	4,300	4,100	3,460	2,590	5,680	7,560	4,850	10,700
27	21	4,400	5,300	7,400	4,320	3,050	2,070	17,600	7,290	4,940	6,570
June 3	22	3,600	5,000	7,600	5,190	2,610	1,870	6,100	5,400	4,730	4,210
10	23	3,500	5,000	6,000	5,700	2,510	1,900	5,410	4,640	5,100	4,650
17	24	4,100	4,200	4,700	3,750	3,490	3,000	7,960	5,170	3,490	4,940
24	25	2,700	4,100	5,500	3,210	3,750	1,650	4,740	4,010	3,100	5,640
July 1	26	2,600	3,100	5,100	2,890	2,990	1,840	3,800	6,870	2,350	3,330
8	27	3,600	3,600	3,800	3,570	3,490	6,350	3,600	10,200	2,080	3,440
15	28	2,600	3,200	4,700	4,620	4,[illegible]20	9,070	8,800	8,230	2,750	3,980
22	29	4,300	3,500	7,500	2,500	6,520	12,600	3,490	5,350	3,160	3,660
29	30	2,700	3,200	17,900	3,120	3,530	5,010	5,120	5,000	1,990	4,460
Aug. 5	31	3,600	4,300	8,400	3,190	6,800	3,750	4,620	5,590	2,510	8,070
12	32	4,700	4,500	8,000	2,920	4,600	3,570	8,040	3,930	2,370	7,670
19	33	3,600	5,400	6,200	4,310	32,200	2,610	6,900	6,070	2,780	3,410
26	34	2,400	5,600	3,800	6,160	6,540	2,990	9,220	2,740	1,570	4,120
Sept. 2	35	2,800	6,200	3,100	2,960	29,500	2,410	4,420	2,580	1,350	2,870
9	36	4,200	7,400	3,600	2,590	9,200	2,110	5,810	2,740	1,780	2,720
16	37	2,500	6,600	3,600	1,740	4,940	1,990	5,660	1,810	1,900	4,320
23	38	2,200	3,500	3,000	1,780	3,690	1,380	3,960	3,060	1,890	10,400
30	39	3,100	2,800	2,500	1,520	3,290	1,280	6,[illegible]70	2,080	6,040	3,750
Oct. 7	40	7,000	3,600	2,600	2,010	2,640	1,140	4,400	1,690	6,200	
14	41	8,600	3,500	1,800	1,520	2,670	1,160	3,140	1,590	1,990	
21	42	17,900	7,700	1,600	1,370	2,720	1,080	2,990	1,730	4,870	
28	43	6,700	10,200	1,800	1,430	2,210	1,250	3,990	2,020	5,060	
Nov. 4	44	4,400	8,000	1,600	1,410	3,880	2,200	4,500	2,390	2,290	
11	45	4,600	4,400	5,000	1,460	3,020	1,730	3,370	3,050	2,390	
18	46	5,200	4,600	2,200	1,370	3,190	1,380	3,160	2,250	3,430	
25	47	3,900	3,900	5,600	1,680	2,510	1,740	2,940	1,910	3,360	
Dec. 2	48	3,300	4,100	4,000	1,550	2,790	1,620	3,750	1,760	6,110	
9	49	6,200	3,600	3,100	1,480	2,580	3,890	11,000	1,830	4,490	
16	50	6,600	4,[illegible]00	3,400	1,560	2,610	2,390	6,880	2,630	4,640	
23	51	8,200	4,600	2,900	1,670	3,630	2,310	5,490	1,540	4,290	
31	52	7,300	7,800	5,300	2,260	6,320	4,470	26,900	3,900	8,290	
Max. daily cfs		71,300	58,800	35,100	38,300	79,700	15,500				
Min. daily cfs		1,630	2,020	1,270	1,020	1,100	879				
Mean for year cfs		8,920	7,490	5,930	5,280	5,380	3,530	5,970	6,350	5,950	

Drainage Areas: Douglas Dam, 4,541 square miles; Dandridge, 4,446 square miles. From January 1, 1939, to March 11, 1942, flows were [illegible] Tennessee, gage. [illegible] changes in [illegible] drainage areas, [illegible] 2, 1942, flo[illegible] Douglas Dam, Tennessee, gage, drainage area 4,543 square miles, corrected for storage changes in Waterville and Douglas Reservoirs.

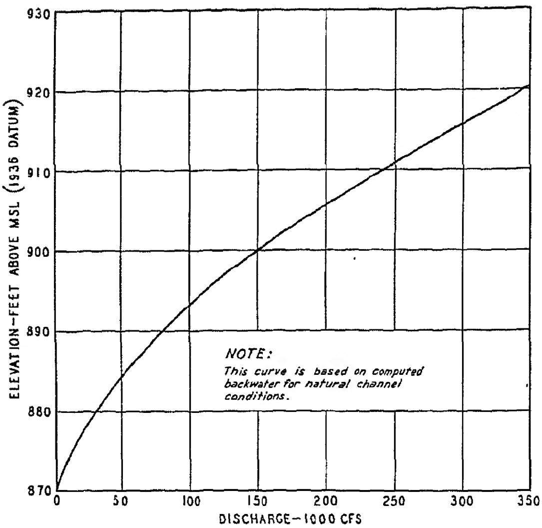


FIGURE 6.—*Douglas Dam tailwater rating curve.*

SELECTION OF SITE

Although the Douglas project was of great importance to the national defense program, it became obvious that the site should be selected primarily with regard to its suitability in the long-time multiple-purpose program. The large drainage area to be controlled made it imperative that the dam be placed as near the mouth of the stream as satisfactory dam and reservoir sites would permit.

In House Document No. 328, 71st Congress, 2d session, the Corps of Engineers recommended sites at Kiker's Ferry, mile 28.8 and at Dandridge, mile 44.8. Not only were the foundations and abutments at these sites questionable, but also both dams were required to provide the minimum storage considered to be desirable and the maximum reservoir level required at the upper site would have obliterated the greater portion of the town of Dandridge.

A site that was favorable topographically was found at Douglas Bluff, mile 32.3, and preliminary drilling indicated that although cavities existed throughout the site they could be successfully treated at not too great cost.

Studies showed that the maximum feasible pool level at Douglas Bluff would provide satisfactory storage but would not inhibit the protection of Dandridge or involve excessive costs for relocation of highways and railroads. Since the site at Douglas Bluff was the only one on the river that met all requirements to any reasonable degree, it was finally selected.

RESERVOIR ELEVATIONS

The original studies contemplated a dam with crest gates at elevation 997 and a minimum reservoir level of 934. It was estimated

that this would provide 1,230,000 acre-feet of controlled storage. A surcharge of 5 feet to pass the maximum flood would have added 150,000 acre-feet of uncontrolled storage.

More detailed topographic surveys indicated that these estimates of volume were too high and accordingly the top of gates was raised to elevation 1002. This provides a controlled storage volume of 1,311,000 acre-feet down to elevation 935, which is the level established for flood control on January 1. In extremely dry years a further draw-down to elevation 920 provides a total useful storage volume of 1,420,000 acre-feet.

The southwesterly rim of the reservoir is formed by a chain of low lying shale hills of considerable extent. Elevation 1002 required saddle dams in the gaps between a number of these hills. A higher pool level would have increased the number and size of these dams, as well as increasing the length and decreasing the effectiveness of the barrier presented by the hills themselves. Figure 7 shows the area and volume curves for Douglas Reservoir.

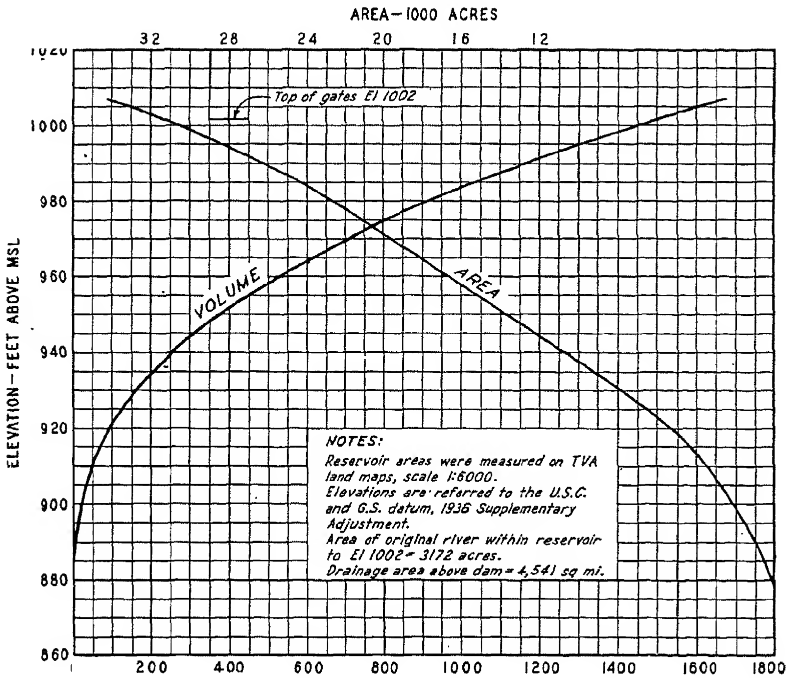


FIGURE 7.—*Reservoir areas and volumes.*

TYPE OF STRUCTURES

Description of site

The dam is located at a convergence in the valley bottom to a width of approximately 950 feet in an otherwise broad, flat, and fertile flood plain (fig. 8). The river channel at this point is only about

500 feet wide. The left or south bank rises rather steeply to elevation 950 and then continues on a gentle slope to about elevation 1060. Eight earth embankments or saddle dikes were required to close depressions along the shale ridge forming a continuation of the left abutment. The right bank shows more evidence of a flood plain in the over-bank area, and its slope rises gradually and uniformly to well above elevation 1100. Bedrock in the vicinity of the dam site consists of gray dolomite and light gray to blue limestone.

General layout

The configuration of the site is well adapted to the same general layout as used at Cherokee Dam. The powerhouse was located on the right flood plain where the excavation was moderate, with the spillway reaching across the river to the abrupt rock cliff at the left abutment. These structures are flanked by concrete gravity bulkhead sections.

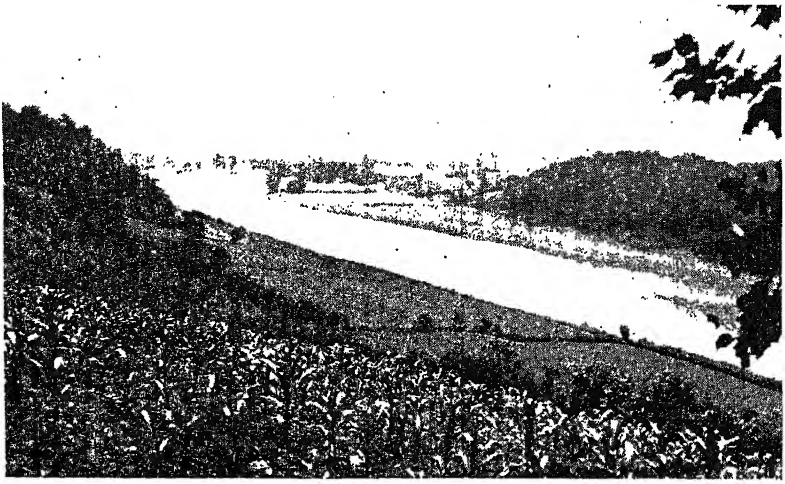


FIGURE 8.—*Douglas Dam site, looking upstream.*

The powerhouse is a duplicate of that at Cherokee. The Francis-type turbines, two of which were installed initially, are rated at 41,500 horsepower at 100-foot head. Provision was made for a third unit in the powerhouse building and a bulkhead opening was provided through the dam for the installation of a possible fourth unit.

The spillway is also a replica of the one at Cherokee except that 11 gates are used instead of nine and that the height isn't as great. Eight sluiceways are provided to maintain the reservoir at low elevation during the floor season.

The use of the Cherokee design in this manner not only saved the time of designers and draftsmen who were hard pressed, but also permitted duplication of both permanent and construction equipment, but repetition of the same job greatly simplified the work of the construction forces.

Eight low saddles along the southwest rim of the reservoir, to the south of the main dam and between Flat and Millican Creeks were

closed with earth dikes or so-called saddle dams. The first one and the largest crosses the head of Flat Creek and required about 500,000 cubic yards of rolled earth fill. All of these dikes are fully riprapped on the upstream face. A tabulation of the principal data relating to all structures is contained in appendix A. The general scheme of development is shown in figure 14.

Spillway capacity

The flood of March 1867 and that of February 1875 were the largest known at Dandridge and probably reached about the same stage there. The maximum discharge for both floods is estimated at 150,000 cubic feet per second at both Dandridge and the dam site. The floods of 1901, 1902, and 1916 were all several feet lower than the 1867 and 1875

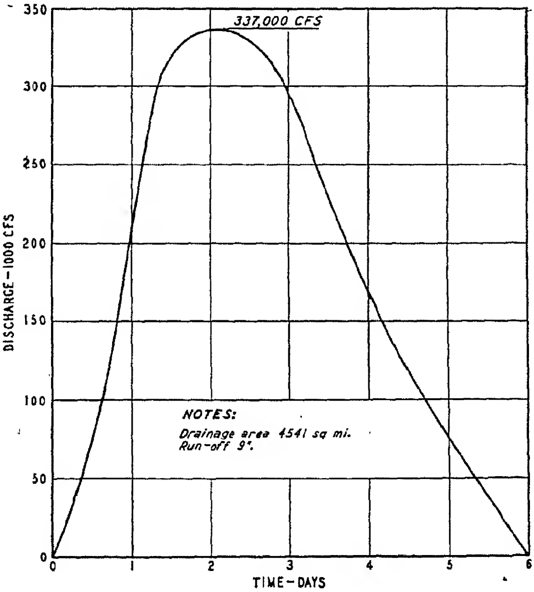


FIGURE 9.—*Maximum estimated flood on the French Broad River—Douglas Dam site.*

stages. The design flood for Douglas is based on the theoretical formula of 5,000 times the square root of the drainage area, or 337,000 cubic feet per second. An assumed hydrograph for this flood is shown in figure 9. The spillway will pass 325,000 cubic feet per second with all gates open and headwater at elevation 1002. In addition to the 11 crest gates, 8 outlet sluices through the dam have a total capacity of about 29,000 cubic feet per second with the reservoir at elevation 1002 and tailwater about elevation 920. The spillway capacity, therefore, at normal reservoir level is approximately 354,000 cubic feet per second, exclusive of any flow passed through the turbines. Under this condition the level of the water in the reservoir will be 15 feet below the top of the embankments. Figure 10 shows spillway and outlet conduit capacities as designed. Subsequent calibration of the spillway

openings showed that actual discharges were about 7 percent higher than the design curves indicate.

Dandridge dike

Jefferson County, Tenn., had a population of about 18,000 in 1940; and the county seat, Dandridge, was the home of approximately 500 people. Both the town and the county showed less than 10 percent gain in population during the two census periods between 1920 and 1940. The total estimated direct damage to the town of Dandridge, if unprotected from the reservoir, was estimated at not less than $465,-000. All the business district, the courthouse and jail, and about 1,000 feet of the main highway through the town are below the maximum water level of Douglas Reservoir. Most of the residential district, including schools and churches, is well above maximum reservoir level but would have suffered substantial indirect damage even though located on the surrounding hills.

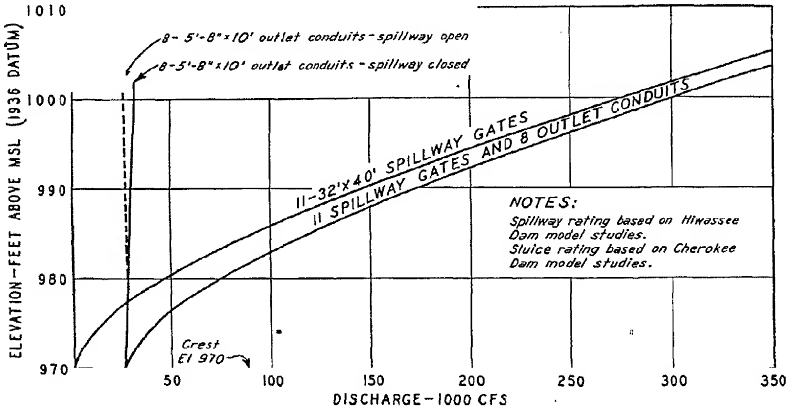


FIGURE 10.—*Douglas Dam spillway and outlet conduit capacities. (Calibration of prototype indicated these capacities should be increased approximately 7 percent.)*

The two creeks flowing through the town drain, in all, 550 acres. They join near the center of the business district to flow through a narrow defile into the French Broad River. The protective dike that was built across the lower end of creek valley left the town practically undamaged except for nine low-price residences and two small business establishments; also, state and county roads required only minor adjustments to accord access to the new county bridge across the river at Dandridge. Minor adjustments were necessary to the existing street, water, and sewer systems in the town. Figure 11 shows the completed dike and a portion of the town of Dandridge in the background.

In addition to constructing the dike, the TVA maintains and operates the protective works.

The dike was built to elevation 1009, or 7 feet above the top of the crest gates on the dam. It was located as close to the river as the outlet

slopes would permit in order to involve the minimum amount of street adjustment and building relocation.

Two small diversion dams and conduits were designed to divert the run-off from all but 55 acres of the area drained by the creeks around the end of the main dike for discharge by gravity into the main reservoir. The capacity of the conduits is equivalent to a storm run-off of 2 inches per hour. The frequency of a storm of this intensity is estimated to be about once in 100 years. The remaining run-off collects in the natural creek channels behind the dike and is pumped into the reservoir. The pumping plant has a capacity for removing 12 inches of water per day from the 55 acres of undiverted watershed. Run-off temporarily exceeding pump capacity can be stored behind the dike to elevation 976, a level 4 feet lower than the deepest basement in the town. During most of the year the water level in the main reservoir will be low enough to permit the internal drainage to discharge by gravity directly into the reservoir through a headgate and outlet culvert incorporated in the pumping plant.

FIGURE 11.—*Dandridge dike, showing a portion of the town in the background.*

RESERVOIR CLEARING LINES

The reservoir was to be drawn down to elevation 935 by the beginning of the general flood season every year. Elevation 930 was, therefore, established as the lower clearing line above which all trees, fences, buildings, and similar obstacles were removed. Although the reservoir may occasionally be drawn as low as elevation 920 for power releases, such conditions will occur probably after the usual recreation season. Elevation 1002, the top of spillway gates, was established as the upper clearing line.

FLOOD CONTROL

With a drainage area above Douglas Dam equal to 21.2 percent of the total drainage area above Chattanooga, the French Broad River has contributed heavily to all major floods there. Figure 12 shows

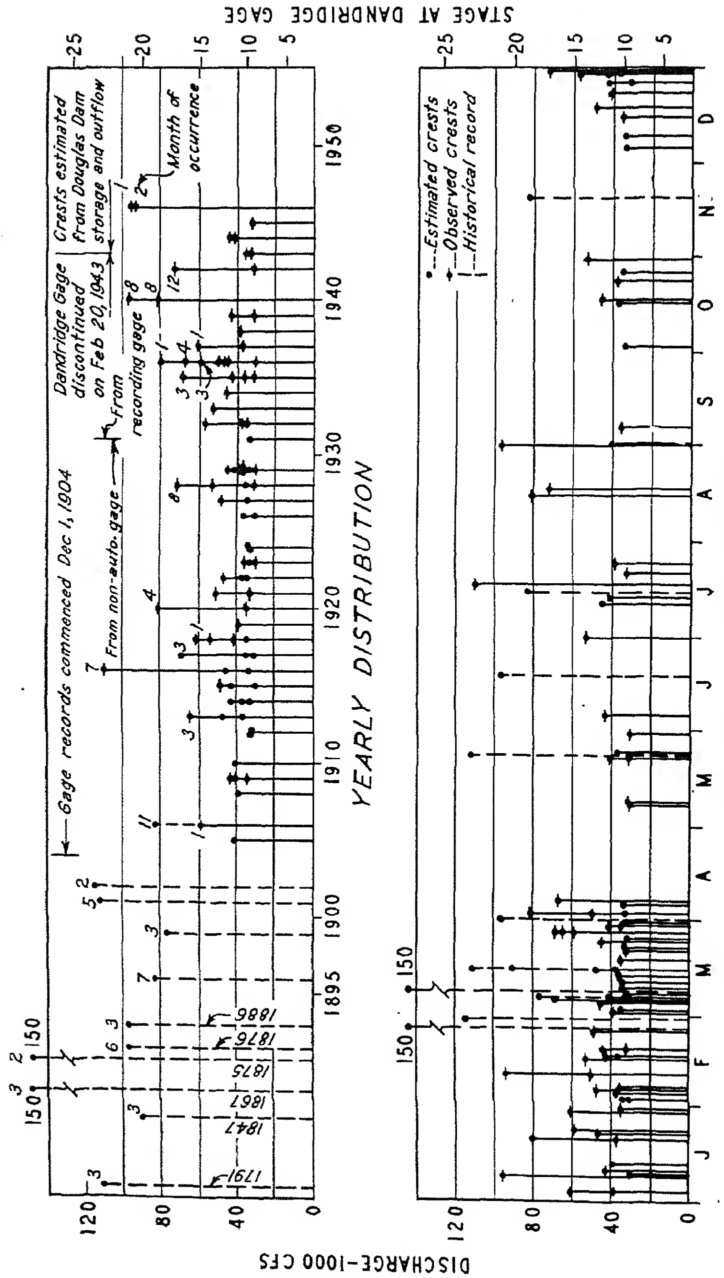
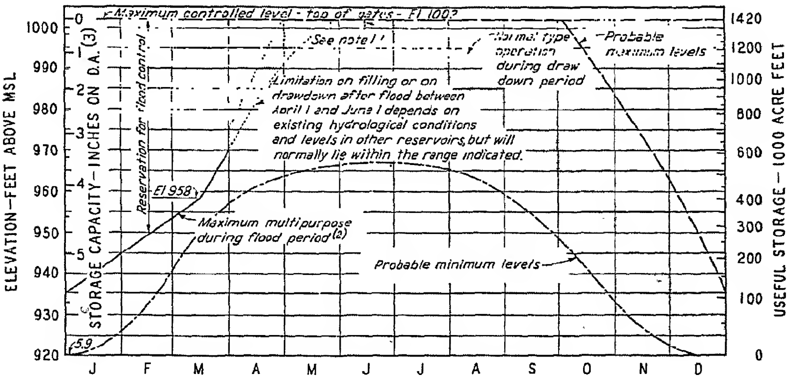


FIGURE 12.—Distribution of floods at Dandridge, Tenn.

the distribution of floods at Dandridge. High-water marks on both the lower French Broad River and the Pigeon and Nolichucky branches show that the French Broad was a major factor in the big floods of 1867 and 1875, the two highest of record at Chattanooga. High stages along the lower French Broad were also encountered in the flood of 1917. The relation of peak flows on the French Broad River at Dandridge to those on the Tennessee at Chattanooga during two large floods is shown by the following recorded flows:

Date of flood	Peak flow at Chattanooga, cubic feet per second	Peak flow at Dandridge, cubic feet per second	Ratio percent
April 1920	298, 000	84, 500	28. 3
April 1936	220, 000	70, 000	31. 8

NOTE.—These figures indicate that the ratio of peak discharges on the French Broad at Dandridge and the Tennessee at Chattanooga has been substantially greater than the proportionate size of their relative drainage areas.



NOTES:

1. Reservoir would normally be drawn down 2 feet or more through turbines to provide storage space for control of runoff from freshets.
2. To be exceeded only during flood control operations.
3. Based upon drainage area, 4541 square miles.

FIGURE 13.—*Reservoir operation diagram.*

Estimates compiled for flood volumes on the various tributaries of the Tennessee River during the Chattanooga floods of 1917, 1918, and 1920 indicate that the French Broad River contributed on an average of about 14.1 percent of the total flood flow at Chattanooga. In a series of nine floods, for which complete data are available, the French Broad contributed on an average of 15.7 percent of the total flood flow at Chattanooga. The records show that the French Broad consistently contributes a proportionately larger volume of flood discharge than any of the four major tributaries above the city.

According to the rule curve devised for the multipurpose operation of Douglas Reservoir (fig. 13), the following storage capacities are reserved for flood control during the winter and early spring season:

Date	Above elevation	Storage volume, acre-feet	Equivalent inches depth on watershed
January 1	935	1,311,200	5.41
March 15	958	1,019,800	4.21
April 1	970	804,800	3.33

NAVIGATION

An analysis of water-borne traffic potentialities on the Tennessee River tributaries, made in 1940, indicated that navigation improvement on both the French Broad and Holston Rivers will probably never be economically feasible since both rivers serve virtually the same trade and manufacturing areas. Later analyses indicate that while canalization of the Holston River may someday be justified, the same in all probability will not be true for the French Broad River. No provision was made either for a future lock at Douglas Dam or to provide a minimum depth of channel in the upper reaches of the reservoir. During construction, the reservoir was prepared for the safe navigation of small craft, as explained in chapter 6.

Recommended clearances for bridge crossings within the reservoir area (table 36) were set to conform with the standrd clearances for secondary channels adopted by the TVA in November 1941, with the exception that a minimum horizontal clearance of 100 feet was required in conformity with the rules of the United States Corps of Engineers. These clearances are sufficient for malaria control boats and for most pleasure craft with the possible exception of sailboats. Since no bridges exist in the lower part of the reservoir where conditions favorable for sailing are found, the adopted vertical clearance of 15 feet above maximum pool and 100 feet horizontal clearance are considered sufficient for the Douglas Reservoir.

Releases from Douglas Reservoir will aid in maintaining minimum depths for commercial navigation on the Tennessee, the Ohio, and the Mississippi Rivers.

POWER

Provision was made for an ultimate station generating capacity of from 112,000 to 120,000 kilowatts in four units. The first unit to be installed at Douglas was originally ordered for the Cherokee project. By transferring this unit to Douglas, dependable power was assured for wartime use at a much earlier date than would otherwise have been possible. A second unit of equal capacity and duplicate design was later erected to complete the initial installation of two units. Both turbines are rated at 41,500 horsepower at full gate and under a head of 100 feet. The generators have a capacity of 30,000 kilowatts each with a 60 degrees centigrade temperature rise and 0.9 power factor.

Water releases from the reservoir will generate energy not only at the Douglas plant but also at all down-river plants. The total head at all these plants, including Douglas, through which storage release

will flow, is approximately 580 feet under average operating conditions.

It was estimated that the construction of the Douglas development would make available an additional 100,000 kilowatts of continuous power to the TVA system when operated primarily for power, as a part of the war emergency power program.

Under multipurpose operation a substantial portion of the reservoir volume will be reserved for flood-control storage during the winter and early spring season (see fig. 13). With this type of reservoir control the primary energy contributed to the system will be substantially less than when operating primarily for power and will result in a corresponding increase in secondary and dump energy. Under such conditions it was estimated that the Douglas project, with an initial installation of two units, will contribute 41,000 continuous kilowatts to the potential primary output of the system, including the additional power generated from the released water at the downstream plants. On an average, the output of the TVA system would be increased by approximately 370,000,000 kilowatt-hours annually.

During the period of emergency operation, the entire cost of the Douglas project was charged to power only. Subsequently, under multipurpose operation the capital cost was distributed between flood control, navigation, and power. Under such allocation the cost of primary energy at station switchboards was estimated at 2.36 mills per kilowatt-hour. This unit cost includes a credit for the value of secondary energy converted to primary and also includes the cost of the additional generating capacity installed at down-river plants for the purpose of developing the additional primary energy available at a 70 percent load factor.

The two turbines initially installed at Douglas were designed to operate at Cherokee with best efficiency under a head of about 110 feet. Under conditions at Douglas the optimum head for best efficiency will be more nearly 90 feet. Therefore, with the future installation of a third unit it will be possible to increase the efficiency of the overall water-use at Douglas by rating the new turbine at a somewhat lower head. A third unit like the two now installed would increase the secondary and dump energy output by a total of 40,000,000 kilowatt-hours in an average year and with no increase in primary energy. On the other hand, a third unit designed for best efficiency at a 90-foot head will increase the potential primary power at Douglas by about 2,000 continuous kilowatts and also provide approximately the same average annual amount of secondary and dump energy, or 40,000,000 kilowatt-hours. This would increase the primary power contributed by Douglas Reservoir to 43,000 continuous kilowatts and raise the average annual increase in system output to around 43,000,000 kilowatt-hours.

Estimates were based on stream flow during the 12-year typical period (1921 to 1932, inclusive) with allowances for water and utilization losses but with no deductions for transformation and transmission losses.

SOCIAL AND ECONOMIC STUDIES

The effect of Douglas Reservoir upon the general economy of the region as related to population displacement, agriculture, forestry,

industry, recreation, transportation, and local government finances was carefully studied. The studies, prepared largely by the TVA, presented factual data on the general benefits of reservoir construction in comparison with the detriment to agriculture in inundating large blocks of fertile land.

The four Tennessee Counties of Cocke, Hamblen, Jefferson, and Sevier, in which the reservoir lies, were considered as constituting the Douglas region. The wide and fertile bottom lands along the French Broad River made this region one of the most productive farming areas in east Tennessee, with a total population in 1940 of 84,606.

Population

Eighty-three percent of the total population was classified as rural. Seven hundred fifty-seven families lived on farms which were covered wholly or partly by Douglas Reservoir, and approximately 700 families were displaced from reservoir lands. Sixty percent of the total families were those of tenant farmers. Construction of the large protective dike at Dandridge eliminated one of the most serious population readjustment problems. The growth in population in the region is given in table 5.

TABLE 5.—*Population of the Douglas region,[1] 1920–40*

Town and county	1940	1930	1920	Percent change		
				1930–40	1920–30	1920–40
Cocke County	24,083	21,775	20,782	10.6	4.8	15.9
Newport	3,575	2,989	2,753	19.6	8.6	29.9
Hamblen County	18,611	16,616	15,056	12.0	10.4	23.6
Morristown	8,050	7,305	5,875	10.2	24.3	37.0
Jefferson County	18,621	17,914	17,677	3.9	1.3	5.3
Jefferson City	2,576	1,898	1,414	35.7	34.2	82.2
White Pine	497	516	421	−3.7	22.6	18.1
Dandridge	488	446	439	9.4	1.6	11.2
Sevier County	23,291	20,480	22,384	13.7	−8.5	4.1
Sevierville	1,161	882	776	31.6	13.7	49.6
Total	84,606	76,785	75,899	10.2	1.2	11.5

[1] From United States census figures.

Agriculture

Lands adjacent to and within the reservoir had been farmed for over 150 years. Jefferson County alone contained 129,000 acres, of which about 85 percent was in active cultivation. Of the 33,160 acres finally acquired for reservoir flowage, approximately 75 percent was in Jefferson County and constituted a little over 19 percent of its arable land.

The more productive and easily worked bottoms produced 40 to 50 percent of the vegetables packed by four local canning plants. In addition to supplying a ready market for truck crops, these canneries furnished part-time employment to a large number of farm families. Data given in tables 6 and 7 were assembled by local citizens directly interested in agricultural production in the area.

TABLE 6.—*Farm products sold each year from farms affected by the Douglas Dam Reservoir*

Number of farms	324
Number of acres	60,742
Number of families living on farms	757
Value of field corn, sweet corn, small grain and hay	$210,104.00
Value of vegetables	130,660.40
Value of tobacco	99,200.00
Value of livestock and livestock products	574,285.64
Value of fruits	31,100.00
	1,045,350.04
Farm products consumed by the 757 families on the 60,742 acres	226,100.00
Estimated total value of farm products	1,271,450.04

While this table probably constitutes the most reliable information that can be reasonably compiled, several factors require explanation. The total of 60,742 acres was in 757 farms either wholly or partly covered by water; but only 33,160 acres were actually acquired for the reservoir, 30.4 percent in fee and 69.6 percent by flowage easement. The remaining 27,582 acres are still open to unrestricted use. The income from livestock and livestock products is derived in part from the sale of feed by farmers living within or outside the reservoir area and its real value is probably credited twice, first as a field crop and second in livestock production. An average gross income of over $210 an acre at 1946 market prices is shown and would indicate a banner year rather than an ordinary one. Farm management studies show operating expenses approximate 50 percent of gross receipts. After due allowance for these factors the gross farm income was probably in the neighborhood of $400,000 per year off the area inundated. This loss of farm land is offset measureably by the improved agricultural program and new recreational opportunities in the area surrounding Douglas Reservoir. (See "Agriculture," p. 322, and "Recreation," p. 323.)

TABLE 7.—*Selected agricultural data for the Douglas 4-county region, 1930 and 1940* [1]

Item	Douglas region	County			
		Cocke	Hamblen	Jefferson	Sevier
Number of farms:					
1940	10,518	3,119	1,853	2,124	3,422
1930	9,343	2,707	1,501	2,204	2,931
Percent change 1930–40	12.6	15.2	23.5	−3.6	16.8
Total approximate land area 1940 (acres)	978,560	277,760	111,360	203,520	385,920
All land in farms:					
1940 (acres)	679,468	180,508	104,375	172,135	222,450
Ratio, farm land to total	69.4	65.0	93.7	84.6	57.6
Average size of farms (acres):					
1940	64.6	57.9	56.3	81.0	65.0
1930	75.1	72.8	68.8	80.1	76.8
Land available for crops:[2]					
1939 (acres)	459,234	114,755	81,367	128,909	134,203
1929 (acres)	441,326	108,317	73,020	129,192	130,797
Percent change 1929–39	4.1	5.9	11.4	−0.2	2.6
Land available for crops per farm (acres):					
1939	43.7	36.8	43.9	60.7	39.2
1929	47.2	40.0	48.6	58.6	44.6
Farm operators reporting nonfarm work for pay:					
1939 (number)	3,344	937	422	560	1,425
Percent of all operators	31.8	30.0	22.8	26.4	41.6
Average days worked	130	126	197	129	114

[1] United States Census of Agriculture, 1940, first and second series.
[2] Consists of cropland harvested, crop failure, cropland idle or fallow, and plowable pasture.

Forestry

Timber resources of the region suffered little if any loss due to the Douglas project. In 1940 about 75 mills operating in the 4-county region cut approximately 24,000,000 board feet; and three small portable mills operating in the reservoir area cut only 320,000 board feet, or less than 2 percent of the total cut. The problem of transporting timber to woodworking industries outside the region was negligible.

Industry

The most important industries in the region, based on the number of employees, are textile, food-processing, and woodworking establishments. The zinc mines in Jefferson County are located too far away from the reservoir to sustain any damage. The industries vitally affected were the food-processing plants. Of the four canneries located near the reservoir, only one was flooded out. The Stokely Bros. plant in Cocke County is still one of the largest canneries in the south. All the canneries, however, were affected by loss of production from lands inundated. In addition to the 1 small cannery, 11 gristmills, 3 sawmills, and 1 meat-packing plant were below the reservoir level. These 16 displaced industries employed about 10 full-time workers and 62 part-time workers and did a gross business of about $332,000 a year.

Recreation

Most of the wooded area in the region is within the Great Smoky Mountains National Park and the Cherokee National Forest. The former, with the highest mountains east of the Rockies, is a major tourist attraction. Although the reservoir was very close to the national park and forest, it had very little recreational development. Lying as it does on two main routes of travel to the southern Appalachian Mountains, Douglas Reservoir offers now substantial recreational opportunities. The lake has become one of the noted fishing resorts of the valley. It has a maximum width of 1.5 miles, which is exceeded by only two other storage projects. Its shores offer spectacular views of the high mountains to the south. Under multipurpose operation the water surface will rise during a dry year to about elevation 975 by May and recede to about elevation 940 in December, under which conditions the lake may occasionally be too low during the summer season for attractive recreational use. During years of average run-off the lake will remain nearly full throughout the usual recreational season. Being readily accessible to both local and tourist patronage over an excellent system of federal, state, and county highways, it should draw a large number of tourists and vacationists from outside the area due to being contiguous to the Great Smoky Mountains and being within 1 day's journey from populous northern and eastern cities. It has a potential day-use patronage from approximately 75,000 people living in nearby communities and centers.

Highways and railways

Existing systems were all improved, and those remaining above the reservoir were not abandoned or dislocated by construction activities. Highway U S 25E had to be relocated for a distance of about 4 miles, and the highway bridge crossing the French Broad River on this route

was raised. United States Highway No. 70 was raised for a distance of about 0.4 mile, and the Swann Bridge over the French Broad River on this highway was raised from 32 to 41 feet. County road adjustments included two major bridges and many small culverts and side-road approaches. Actual mileages of roads reconstructed by TVA in the Douglas Reservoir area are as follows:

	Miles
Access road	4.07
Access roads improved and surfaced	18.23
State highways	5.34
County highways:	
Principal county highways	35.04
County highways resurfaced	2.90
Tertiary roads	12.66
City streets	.39
City streets resurfaced	1.14
Total for project	79.77

The Southern Railway track from Leadvale to Newport, extending for about 9 miles through the reservoir area, was elevated; and the railroad bridge over the French Broad River at Leadvale was raised. While several small rural communities were inundated, no highly developed residential areas were damaged to any extent.

Effects on local government finances

Adjustments in the services and finances of Jefferson, Cocke, Sevier, and Hamblen Counties were necessary. Dandridge, the only incorporated town within the reservoir area, was protected by a large dike; and the direct effect of reservoir construction upon the town was one of improvement rather than real loss. No other local taxing units were located adjacent to the reservoir.

Financial data for four counties during the fiscal year ending August 31, 1941, are shown in table 8.

TABLE 8.—*Financial data for counties in the Douglas Reservoir*

Explanation	County			
	Jefferson	Cocke	Sevier	Hamblen
Total assessed valuation	$7,487,000	$7,279,000	$3,666,000	$7,991,000
County tax rate	2.47	2.52	3.42	2.19
Revenues, total	361,000	373,000	364,000	275,000
Local sources	219,000	201,000	161,000	178,000
State aid	142,000	172,000	203,000	97,000
Expenditures, total	377,000	429,000	379,000	327,000
School purposes	158,000	170,000	172,000	118,000
Highway purposes	79,000	65,000	76,000	58,000
General purposes	44,000	67,000	34,000	103,000
Debt service	96,000	127,000	97,000	48,000
Net bonded debt, total	864,000	906,000	599,000	410,000
Per capita	46	38	26	22
Ratio to assessed valuation ... percent	11	12	16	5

Revenues from local sources were derived mostly from the taxation of real property and provided a major portion of the total income of all counties except Sevier, were state aid accounted for 55 percent of the total receipts. (In the above tabulation TVA payments in

lieu of taxes are combined with property taxes.) Excess of expenditures over receipts was customarily made up by increases in the floating debt, and the net bonded indebtedness per capita for every county except Hamblen is comparatively high. The per capita public debt of Jefferson County is fourteenth in the list of 95 counties in the state; and that of Cocke County, twenty-fourth. Refunding, rather than retirement of former bond issues, tended to increase the total bonded indebtedness out of proportion to the facilities rendered.

Rough estimates of the assessed valuation and annual county tax levies applicable to purchase area in each county were as follows:

County	Assessed valuation	Annual county taxes
Jefferson	$1, 440, 000	$35, 600
Cocke	248, 000	6, 300
Sevier	100, 000	3, 400
Hamblen	30, 000	650

Taxes on reservoir lands amounted to about 10 percent of the total revenues for Jefferson County and less than 2 percent in the other three counties. No immediate reduction in tax receipts occurred, however, because during the war emergency operation all reservoir lands acquired for the project were temporarily allocated to power purposes, and the full amount of former land taxes was included in the computation of minimum payments in lieu of taxes. Under multipurpose use, 40 percent of the coast of reservoir lands is allocated to power, and payments in lieu of taxes are computed on that portion. Loss of taxes on the remaining portion allocated to public use is of importance to Jefferson County only, since a very small portion of the area retired from taxation is located in the other three counties. The improved agricultural program and recreational development are offsetting factors to this tax loss.

Public facilities immediately affected by reservoir construction and TVA activities are those for schools, highways, health units, and libraries. These services, organized principally on a county basis, shared taxes and state grants, which provided a substantial portion of their support. The TVA cooperated with the counties in relieving the additional burden caused by the influx of construction personnel into the area.

Electric power service is supplied by two retail distributors of TVA power, the Appalachian Electric Cooperative and the Newport municipal system. Figures for the two systems, estimated to be applicable to the vicinity of Douglas Reservoir in 1941, are as follows:

Item	Total, 2 systems	Estimated to be within vicinity of Douglas project
Miles of rural line	175	115
Number of retail customers	4, 200	2, 500
1941 retail sales:		
Kilowatt-hours	17, 268, 000	5, 700, 000
Revenue	$221, 500	$100, 000

Residential consumption for the calendar year 1941 averaged about 1,220 kilowatt-hours per customer, or 24 percent above the annual use reported for the Nation as a whole. The average cost to the consumer was about 2.11 cents per kilowatt-hour, or 43 percent below the national average residential rate for that year.

The wages received by TVA employees during the construction period enabled many residents to improve their homes and business places, to pay off farm mortgages, and to buy modern farm machinery. The TVA, through the state agricultural extension service, maintained a staff of trained agricultural workers to furnish assistance other than financial to farm families in individual relocation and adjustment problems.

Conclusions

It was estimated that direct income for power from Douglas Reservoir would be over $2,400,000 annually, and the less tangible benefits derived from flood control, recreation, and stream sanitation would add another $100,000.

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Chapter 3

DESIGN

The Douglas project was designed as part of the integrated plan to improve navigation and prevent destructive floods and, in addition, to generate electric energy. It is located on the French Broad River about 30 miles above its confluence with the Holston River where they form the Tennessee River about 5 miles above Knoxville. Flood conditions and the available head, storage, and stream flow at this site were identical to those at the Cherokee project to such a degree as to permit practically complete duplication in design and layout. As a result, major economies were secured in both time and expense for design, procurement of equipment, and construction.

The proposed installed capacity for power production was 90,000 kilowatts, consisting of three units of 30,000 kilowatts each, with provisions for a future fourth unit. Only two units were installed initially, however, because of the scarcity of critical materials. One of the two units installed was transferred from the Cherokee project, making it possible to produce power within 13 months after the project was authorized by Congress. The third unit, which was designed as 30,000 kilowatts, has been reduced to 26,000 kilowatts. This was advisable in order to secure the most efficient operation at minimum reservoir levels.

The dam consists of concrete gravity sections located in the original river channel. These sections include the spillway, powerhouse and intake, and nonoverflow sections on both sides of the river. In addition, eight saddle dams were required to close gaps in the reservoir rim in the south ridge, and a dike was required to protect the town of Dandridge.

Foundation for both spillway and intake is Knox dolomite. The flow over the spillway is controlled by eleven 32- by 40-foot radial gates. Two traveling hoists of 60-ton capacity, driven by electric motors, are used to operate these gates. Eight sluices through the spillway provide additional capacity for reservoir control, and a concrete apron and weir form a stilling pool for the dissipation of energy of spillway discharges. The intake contains penstocks, trashracks, gates, and gate hoisting equipment for supplying water to the turbines.

The powerhouse is a reinforced concrete structure of the semioutdoor type with a 225-ton gantry crane mounted on the roof. Equipment is handled by the gantry through hatches over the units and the service bay. The two initial turbines are vertical Francis type with steel scroll cases and are rated 41,500 horsepower at 100-foot head. Generators are directly coupled to the turbines and rated at 33,333 kilovolt-amperes. The draft tubes are concrete elbow type which can be unwatered by placing gates in slots provided near the discharge end

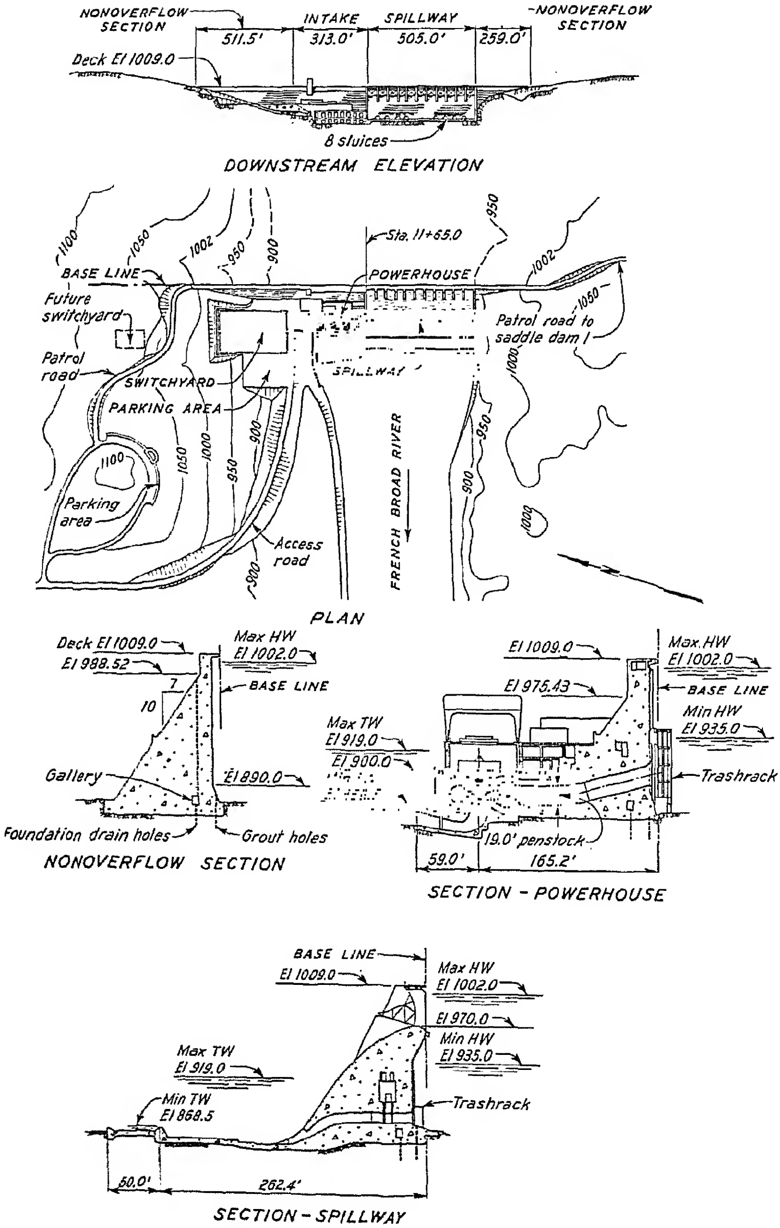


FIGURE 14.—*General plan, elevation, and sections.*

of the tubes and draining to the station sump. Draft-tube gates are operated with a jib-boom hoist on the powerhouse gantry crane.

Both the powerhouse and switchyard are located on the right bank of the river downstream from the base line of the dam. The switchyard was located immediately adjacent to the powerhouse and parallel to the base line of the dam, permitting use of shorter generator and control cables between the powerhouse and switchyard equipment. This arrangement also provided the best possible routing of transmission lines to and from the yard. Location of the main transformers and switching structures within the yard was determined largely by the method adopted for handling and untanking the transformers. This is done by the powerhouse gantry crane. Initially, the yard contained three bays of structures for 154-kilovolt transmission facilities. In 1944 the 154-kilovolt bay No. 1 was added for an autotransformer feed, and the switchyard was extended for the installation of one bank of autotransformers, two 12.45-kilovolt feeders, and the 110-kilovolt line to Waterville.

EARTH EMBANKMENTS

The rim south of the main dam contains 10 saddles at elevations varying from about 20 feet above to 40 feet below maximum headwater level, elevation 1002. Saddle No. 1 is located approximately ¾ mile and saddle No. 10 about 4½ miles from the dam site. Final survey and investigation of the saddle-dam sites showed that no dams were required at sites Nos. 2 and 7, where the saddles are approximately at elevation 1022. The tops of the saddle dams at the eight remaining sites were set at elevation 1017, or 15 feet above maximum headwater level. These dams form a series of earth embankments varying in height from about 10 feet at sites Nos. 4 and 8, approximately 100 feet at site No. 1 and in length from 65 to 1,918 feet.

In addition to the construction of the eight saddle dams, an extensive grouting treatment was required along the rim to prevent excessive leakage, thereby safeguarding the natural slopes of the rim.

Saddle dam No. 1

Three possible sites were originally considered for saddle dam No. 1. The sites were located approximately 1,000 feet apart, with the downstream site at the top of the saddle. The upstream site was soon eliminated since it required nearly 50 percent more material in the dam than the lower sites required and would have necessitated very extensive and costly drainage facilities below the dam. Of the two remaining sites, the middle site was selected because the foundation at this location consists entirely of shale rock formation, while the downstream site, located partly in limestone formation and partly in shale formation, would have required more extensive foundation treatment. The middle site also avoided flooding an area containing a cemetery, a church, and some farms. On the other hand, a dam at this location required provisions for drainage of the area between the dam and the top of the saddle.

Satisfactory material for an earth-fill dam was available about 1 mile from the site. The possibility of constructing an earth-rock dam was also investigated, but suitable rock could not be located close enough to the dam site to justify a design of this type of dam. There-

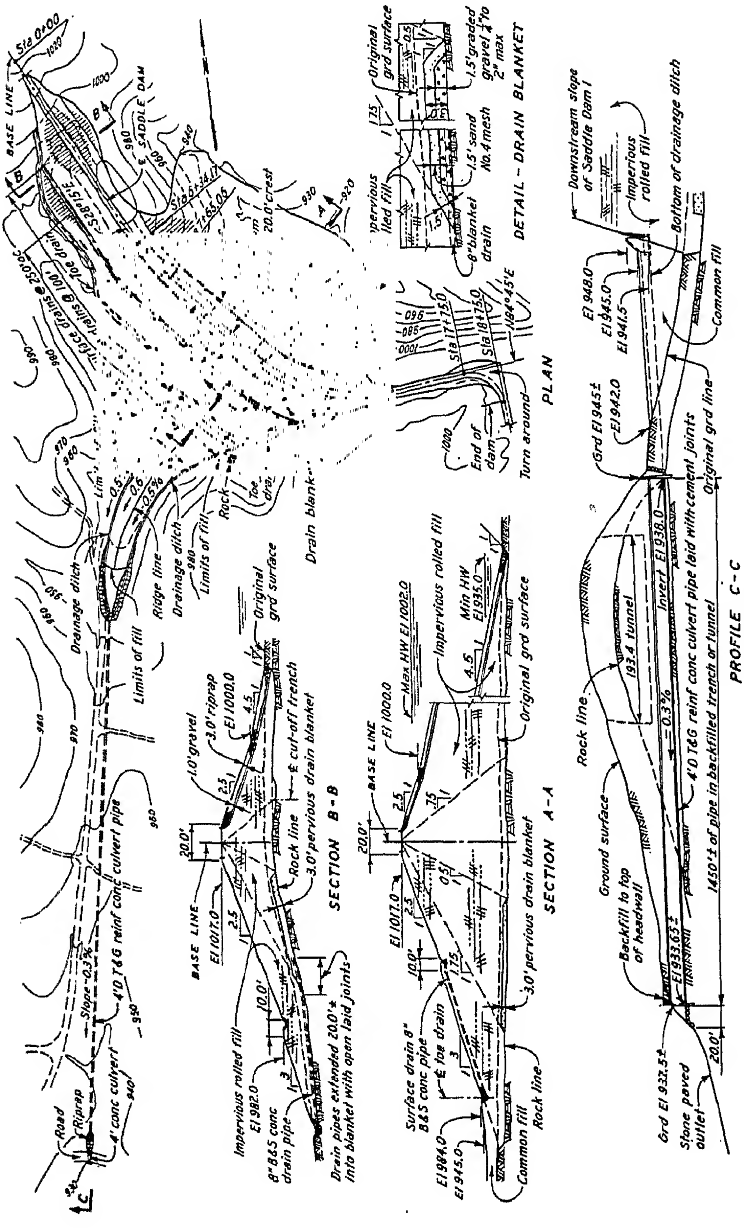


FIGURE 15.—Saddle dam No. 1.

fore, an earth-fill dam was designed to consist of uniformly impervious rolled-fill material with the saturation line controlled by internal drainage. The shallow overburden was removed to rock.

The embankment is about 1,918 feet long (fig. 15) with a maximum height of 95 feet. The upstream slope is 1 on 2.5 from the top of the dam to elevation 1000 and 1 on 4.5 below this level. The entire slope is covered with a 3-foot-thick layer of riprap on a 1-foot layer of gravel. The downstream slope is 1 on 2.5 from the top of the dam to a 10-foot-wide berm at elevation 982, and below this level the slope is 1 on 3. At all sections of the embankment where the foundation is below elevation 990 a drain blanket was placed on the rock foundation in the downstream part. This blanket is placed at a distance from the center line of the embankment equal to one-half the height of the dam at the section in question, and the width of the blanket is 1¼ times this height. The drain blanket is 3 feet thick, consisting of a 1.5-foot bottom layer of gravel graded from ¼ inch to 2 inches maximum and a 1.5-foot top layer of sand passing No. 4 sieve. Grading of the material in the drain blanket was based on tests which indicated that samples of borrow pit clay at the liquid limit would not wash through a filter consisting of sand passing No. 4 sieve and retained on No. 8 sieve. The drain blanket is tapped by 8-inch pipe drains leading to a rock-filled trench along the downstream toe. Where the foundation is below elevation 1000 a cut-off trench was excavated in the rock foundation in the upstream part of the dam at a distance from the center line equal to three-fourths the height of the dam section. The cut-off trench was extended to impervious rock, where possible, or the rock under the cut-off trench was grouted.

From tests in the laboratory, a value of 26 degrees was assumed for angle of internal friction of the earth fill, cohesion of the material was neglected; angle of internal friction of the drain blanket, riprap, and gravel was taken at 45 degrees. With these basic assumptions, the Swedish slip-circle method was used for design. A factor of safety varying from 1.22 to 1.4 was obtained. Laboratory tests on borrow pit material indicated that fill placed so as to obtain an angle of internal friction of saturated fill of at least 26 degrees will have a coefficient of cohesion of from 1,200 to 2,000 pounds per square foot.

The entire downstream slope is seeded to improve the appearance and to prevent erosion. A drainage system, discharging into the toe trench, is provided on the berm at elevation 982 for collection of surface water. A 12-inch drain pipe laid with open joints is placed at the bottom of the rock-filled toe trench. Both the surface ditch of this trench and the 12-inch pipe discharge through two catch basins into the drainage system below the dam.

Saddle dams Nos. 3, 4, 5, 6, 8, 9, and 10

Investigation of the sites for the saddle dams Nos. 3, 4, 5, 6, 8, 9, and 10 showed that the geological conditions were practically uniform within the limits permitted by the topography at each site. Location of these saddle dams was, therefore, determined by the most economical topographic conditions at the sites. The foundations at these sites, and also at sites Nos. 2 and 7, consist of fairly heavy overburden of decomposed shale over shale-rock formation. Satisfactory material for rolled earth-fill dam sections was available near the dam sites. Material in the borrow pits consisted mainly of clay to depths of from 1 to 17 feet over shale formation.

Tests performed in the laboratory on borrow-pit samples of clay compacted at field moisture indicated that the angle of internal friction of the saturated clays would be 26 degrees or larger. Tests on samples of loose and compacted shale gave angles of internal friction of 29 and 45 degrees, respectively. The cross section designed for saddle dam No. 1 was, therefore, found to be satisfactory also for the rest of the saddle dams, and the construction plans for these dams were made accordingly.

The natural ground surface was stripped, and the foundation surface was harrowed over the entire base area of each dam. The upstream slopes are protected by a 3-foot-thick layer of riprap on a 1-foot layer of gravel, and the downstream slopes are seeded. Saddle dam No. 3, with a maximum height of about 35 feet and a total length of approximately 650 feet, is the only one of these dams in which it was necessary to construct a drain blanket and a downstream toe drain similar to those constructed for saddle dam No. 1. The maximum height of the other saddle dams varies from about 10 to 25 feet, and the length varies from approximately 65 to 325 feet.

GENERAL DESIGN FACTORS FOR CONCRETE STRUCTURES

Design assumptions

Stability analyses for the concrete structures were made on the basis of the following general assumptions:

1. *Earthquake—*
   Earthquake stresses were disregarded following previous conclusions[1] by the board of consulting geologists that such stresses could be omitted in designing dams in the portion of the Tennessee River drainage area above Guntersville Dam.
2. *Weights—*
   (*a*) Weight of concrete, 155 pounds per cubic foot.
   (*b*) Weight of water, 62.5 pounds per cubic foot.
   (*c*) Drained weight of fine fill materials, 120 pounds per cubic foot.
   (*b*) Weight of water, 62 5 pounds per cubic foot.
   (*d*) Drained weight of coarse fill materials, 105 pounds per cubic foot.
   (*e*) Buoyant weight of fill materials, 65 pounds per cubic foot.
3. *Uplift and Drains—*
   (*a*) Hydrostatic uplift was assumed to vary uniformly from full headwater pressure at the upstream face of the dam to 50 percent of the headwater pressure at the line of drains and then to tailwater pressure at the downstream face.
   (*b*) The uplift pressures were assumed to act over two-thirds of the area of the base section under consideration either within the concrete or between concrete and rock.
4. *Concrete structures subject to earth pressure—*
   Earth pressures were calculated as active pressures on both the upstream and downstream faces of the dam. The internal angle of friction for the fill (θ) was taken equal to 32 degrees and the friction of the fill on the concrete structure equal to 16 degrees.
5. *Foundation stresses—*
   (*a*) Maximum allowable compression on rock equal to 500 pounds per square inch.
   (*b*) No tension allowed except in special cases as noted under the descriptions of the structure designs, in which cases a maximum tension of 15 pounds per square inch was allowed.
   (*c*) Maximum allowable average shear equal to ¼ (250+0.65 fv) pounds per square inch where fv=average intensity of stress normal to the section.

[1] Tennessee Valley Authority Technical Report No. 6, *The Chickamauga Project*, appendix B, p. 349.

6. *General design of gravity sections—*
   The apex of the basic triangle forming the section of the nonoverflow dam was located at elevation 1004. The downstream slope was set at 10 on 7, which, combined with a vertical upstream face, produced a section showing no tension for hypothetical water level at elevation 1004. For actual maximum water elevation 1002 a small compression would, therefore, exist at the upstream face of the dam. In addition, a 3 on 1 batter was used at the heel to provide an additional base width of 10 feet where the dam was at maximum height. For sections of moderate height at the abutments this extension was elimilated. For the spillway section the same general base stresses were attained. The ogee shape of the crest provides a heavy top, and a downstream slope of 10 on 6 below the ogee was enough to obtain the desired base stresses.
7. *Gravity sections with penstocks and sluiceways—*
   Where holes and openings in the dam are large enough to affect base stresses the designs were based on the section in which the openings occurred.

Joints

Vertical contraction joints were placed at convenient intervals in the concrete gravity sections of the dam, the spacing being selected primarily to suit the spillway and intake structures. These joints extended from the foundation to the top of the structure so that each gravity section acts independently as a block. No keyways were formed in the faces between adjoining blocks.

Horizontal construction joints in the mass concrete were placed at approximately 5-foot intervals with a minimum time lapse of 72 hours between successive placements.

Measurement of foundation uplift pressures

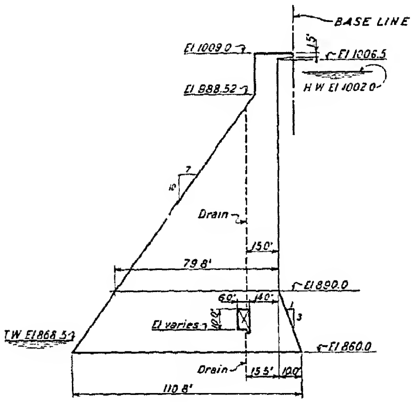
A total of 20 uplift pressure gages was installed at the foundation level for the purpose of obtaining representative measurements of the uplift pressure under the concrete structure and to check the adequacy of the drainage system. The pressure readings are taken at panels installed in the drainage gallery. Some comprehensive results of the uplift studies on Douglas Dam are given in appendix C.

Deflection measurements

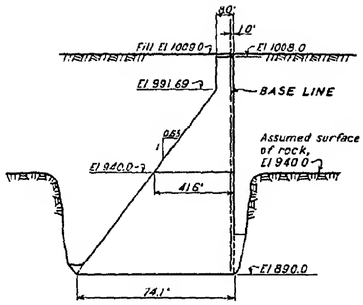
A system for measuring the lateral deflections of various portions of the concrete structures was installed. This installation included the placement of 11 brass plugs in the concrete at the top of the dam in a true line and referenced to points located on stable foundations at such a distance away that they were not affected by the filling of the reservoir.

NONOVERFLOW SECTION

With the intake and spillway located in the natural river channel, the nonoverflow sections form the bulkheads between the intake and the right abutment and between the spillway and the left abutment. They are identified as blocks 1a to 11 and 29 to 35, inclusive. In general, the blocks are 46 feet 6 inches long. This length was chosen the same as the length of the spillway blocks in order to simplify form work. Exceptions to the standard block length occur at the right abutment, at the junction between spillway and left nonoverflow section, and at the left abutment, where it was necessary, after final excavation, to adjust the location of contraction joints to suit the foundation rock profile. In the original layout these blocks were all of the standard length.



NONOVERFLOW



LEFT ABUTMENT

EL	CASE NO.	ΣH KIPS	ΣV KIPS	STRESSES LB SQ IN. fu	fd	AVERAGE SHEAR
890	I	—	727	129	-3	—
	II	391	599	10	95	34
860	I	—	1169	125	22	—
	II	628	996	10	115	39

Note:
Analyses made for 1.0' length of dam

EL	CASE NO.	ΣH KIPS	ΣV KIPS	STRESSES LB SQ IN. fu	fd	AVERAGE SHEAR
940	I	—	220	76	-3	—
	II	68	299	33	67	11
890	I	—	670	128	-3	—
	II	340	950	12	166	32

Note:
Analyses made for 1.0' length of dam.

FIGURE 16.—*Nonoverflow dam and left abutment—Stability analysis.*

The nonoverflow dam is designed as a gravity section with a downstream slope of 10 on 7 with the exception of blocks adjacent to the left abutment, which are partially in backfill. On these blocks the downstream slope was steepened to 10 on 6.5, while the upstream face was made vertical except that a batter of 3 on 1 was used near the bottom of the higher blocks to increase the base width a maximum of 10 feet to provide a better distribution of base pressures. Figure 14 shows a typical cross section.

The top of the dam is at elevation 1009 and includes space for a service road of the same width as the deck over the spillway. The 18-foot-10-inch-wide road is obtained by extending a cantilever 8 feet upstream from the 10-foot-10-inch-wide top portion of the dam.

In the stability analyses of the nonoverflow sections the following cases were considered:

Normal section:
- Case 1—Reservoir empty.
- Case 2—Headwater at elevation 1002 and tailwater at elevation 868.5.

Section with backfill:
- Case 1—Reservoir empty and no fill.
- Case 2—Headwater at elevation 1002 and tailwater at elevation 868.5, with active pressure from backfill.

The results of these investigations are shown in figure 16.

Where the top of the dam approaches the finished grade at the abutments the upstream cantilever is terminated; and adjacent blocks, block 1a at the right abutment and block 32 at left side, are wid-

ened to accommodate the full width of the roadway, concrete parapets, and other architectural features.

A 6-foot-wide by 10-foot-high continuous drainage and inspection gallery runs from block 5 through the intake and the spillway, terminating at the steep bluff at block 28. The gallery is located 14 feet from the upstream face of the dam and follows roughly the foundation level of the dam. Originally, no gallery was planned in the left portion of the nonoverflow dam. However, a great number of seams and cavities in the foundation made it necessary to carry the excavation much deeper than had been anticipated, thereby increasing the height of the dam and making it desirable to add a gallery across the top of the bluff from block 28 to the end of block 33. This gallery is connected to the operating gallery in the spillway by a spiral stairway and to the lower drainage gallery by a 3-foot shaft.

FIGURE 17.—*Spillway.*

The grouting procedure for the foundation, the foundation drainage system, and contraction and construction joints are features common to all concrete structures of the dam and are treated in the section describing the spillway.

SPILLWAY SECTION

The features of topography and geology made the site excellently suited for locating the spillway and the intake structure in the river channel.

The spillway (fig. 17) is a gravity-type structure, divided into blocks 46 feet 6 inches wide, with contraction joints placed at the center of the overfall midway between the piers. The crest is an ogee-type overfall section placed at elevation 970 and surmounted by eleven 40-foot-wide by 32-foot-high radial gates. The spillway has 11 openings 40 feet wide, separated by 10 reinforced concrete piers 6 feet 6 inches thick. The over-all length is 505 feet. The operating deck is at elevation 1009, on which are located the traveling hoists and dog-

ging devices used for radial gate operation. Eight sluiceways through the lower portion of the spillway are controlled by slide gates to operate in conjunction with the spillway for rapid draw-down in advance of floods or to supplement downstream flows in periods of low water when the reservoir level is below the spillway crest elevation. A general cross section is shown in figure 18.

Hydraulic design

The maximum flood to be passed through the dam was estimated to be about 337,000 cubic feet per second with the reservoir at maximum level at elevation 1002. This resulted in a spillway with eleven 40- by 32-foot gates having a total discharge capacity of 304,000 cubic feet per second. In addition to this, there are eight sluices in the lower portion of the spillway dam with a combined discharge capacity of 26,000 cubic feet per second. Total discharge capacity under maximum flood conditions is, therefore, 330,000 cubic feet per second exclusive of flow which can be passed through the turbines.

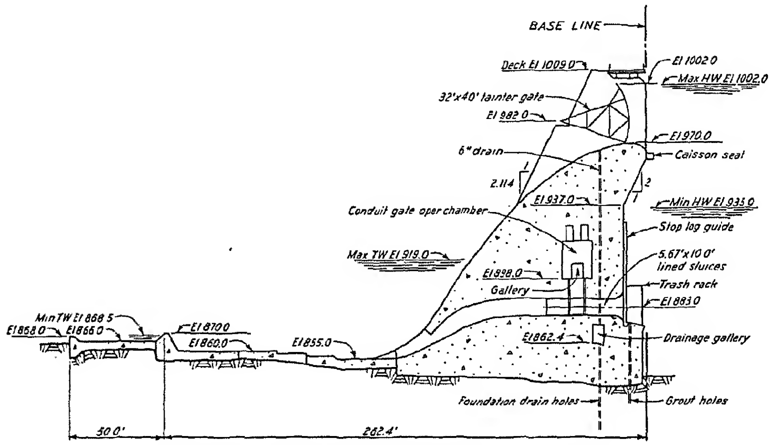


FIGURE 18.—*Spillway dam—General cross section.*

The spillway is shaped to fit the nappe of a shooting velocity of discharge with the radial gate opened 1 foot. For all other gate openings the nappe is always lower, thereby assuring a positive pressure on the face of the spillway for all conditions of gate openings.

Eight sluices through the spillway are each controlled by two slide gates 5 feet 8 inches by 10 feet 0 inch placed in tandem. These gates are essentially duplicates of the slide gates used at Norris Dam. The downstream gate is normally used for operation of the sluiceways, and the upstream gate is used only for emergency closure or to allow maintenance of the downstream gate.

Exit ends of the conduits were built with a 15-percent nozzle constriction, which insures positive conduit pressures and should eliminate any cavitation difficulties. Sluice exit nozzles were simultaneously flared horizontally and flattened vertically to spread the jet over the maximum width of the apron and also bent downward so that the energy of the jet would be absorbed by the bucket pool.

To protect the foundation rock against scour and undercutting, a concrete apron extends about 200 feet downstream from the spillway. Sound rock was found close to tailwater elevation over most of the apron area, and model tests indicated that a stepped apron with a relatively high sill at the downstream end would be required to reduce turbulence. It was also found necessary, through the model tests, to add a strip of paving below the main sill to protect the apron from undercutting during sluice operation, especially when one or two sluices were operating at low tailwater elevation.

As excavation was progressing it became evident that it would be necessary to go much deeper in the right half of the apron area than was originally anticipated. To save concrete, designs were altered to lower the apron in this area as far as possible and still maintain the good hydraulic performance obtained in the original apron design. Several schemes for lowering the apron were tested in the hydraulic laboratory. The apron developed from these tests follows roughly the final rock excavation with the following limitations: top of apron in block 18, which is close to the right training wall, was fixed at elevation 845; top of apron in other blocks varies to suit excavation, but the top of each block was kept level throughout; and the top of the sill provided at the downstream end of the apron was set at elevation 855 for the full length of the lowered apron. To fit the new apron to these conditions, the bottom of the sluices was continued on a 6 on 12 slope with a transition to elevation 845 on a 25-foot radius. Where the top of apron is at a lower elevation there is a vertical drop at the end of the sluice from elevation 845 to top of apron.

Along the right side of the apron a training wall extends from the powerhouse to the end of the apron. Top of this wall is at elevation 900, or at a depth below maximum tailwater elevation determined by model studies. Model tests also indicated that the best hydraulic results would be obtained without any extension of the wall beyond the end of the apron.

At the left side of the apron protection is obtained by lining the steep rock face with concrete to elevation 883.

Model studies

Extensive model tests had already been made for the Cherokee project. Supplementary tests were made for the Douglas project on a 1 : 70 scale model. Tests were made on several alternate modifications of the apron caused by the deep rock excavation. Appendix C includes a detailed report on these studies.

Stability analysis

The spillway section is designed as a gravity structure on the basis of the general design assumptions outlined on page 48.

In the final design the dam was made safe under the following critical conditions of loading, all other loadings being less severe:

Case 1—Dead load only.

Case 2—Headwater at elevation 1002 and tailwater at elevation 868.5 with radial gates and sluice gates closed.

Case 3—Headwater at elevation 1002 and tailwater at elevation 868.5 with a floating bulkhead in one bay and the radial gate closed in the adjacent bay. This case partially determined also the pier reinforcement, giving an unbalanced water load on the pier.

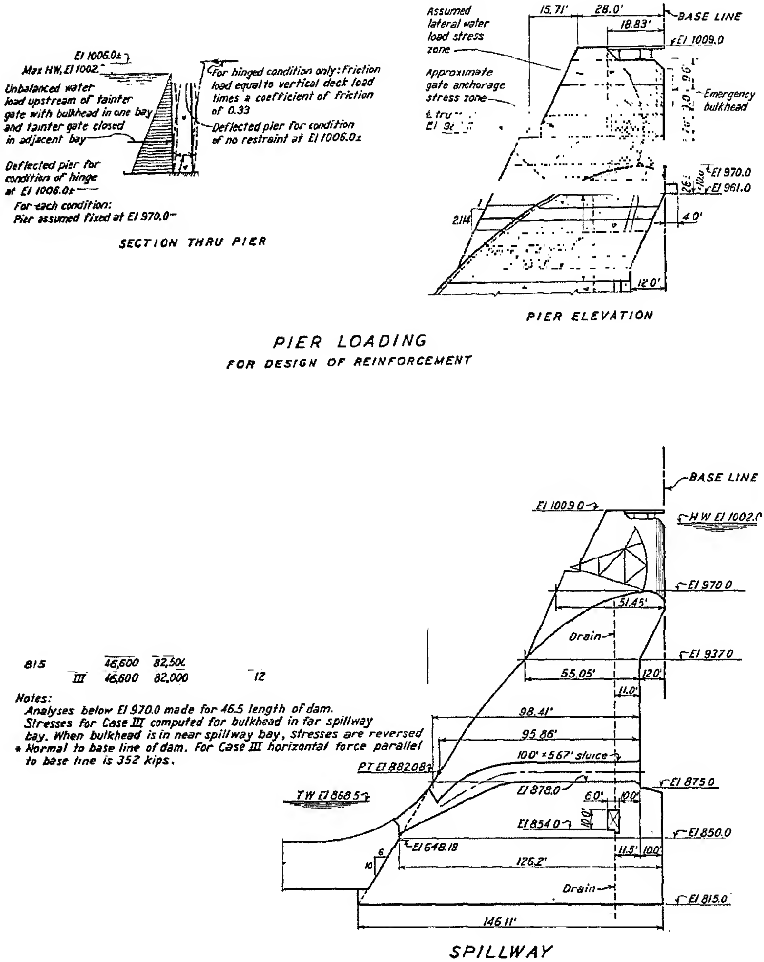


FIGURE 19.—*Spillway dam—Stability analysis and pier loading.*

Analyses of these cases were made for base sections as follows:

1. At elevation 850, the assumed foundation level.
2. At elevation 878, the floor of the sluiceways through the spillway.
3. At elevation 937, the point of break in the upstream face of the dam just below the 12-foot overhang of the ogee section.
4. At elevation 970, the spillway crest and point of analysis for stress in piers.

The results of these analyses are shown in figure 19. Two conditions were considered under case 3 for the design of the pier reinforcement. In both conditions the pier is assumed fixed at elevation 970. However, in one instance the pier is assumed hinged at elevation 1006 and in the other assumed free, acting as a cantilever. For the hinged condition the horizontal reaction was assumed to be a friction load from the

spillway deck equal to the vertical deck load times a coefficient of friction of 0.33. These loading conditions are shown in figure 19.

Contraction and construction joints

Contraction joints in the spillway dam are located midway between piers, dividing the structure into blocks 46 feet 6 inches long. No keys were used in the contraction joints, and the joints were not grouted. The contraction joints are sealed with 20-ounce copper seals. Double seals are placed near the upstream face, and a single seal is embedded around galleries and shafts.

The longitudinal construction joints in the apron match the contraction joints in the overfall section at 46-foot-6-inch centers. Construction joints were also placed parallel to the axis of the dam to divide the apron into rectangular blocks not over 50 feet long.

The horizontal construction joints in the mass concrete were generally placed at intervals of not over 5 feet. The lifts in the piers, however, varied in height from 7 to 10 feet to facilitate construction.

Foundation grouting and drainage

Grouting.—To prevent percolation and seepage under the concrete structures, a grout curtain was placed near the upstream face. A detailed plan for treating the foundation was prepared; but as the foundation was exposed by excavation and more thoroughly explored as the construction progressed, variations from the plan were made to fit more expediently the actual field conditions. The plan called for a grout curtain to seal effectively all seams in the rock to a depth of at least 60 feet and grouting operations to be so conducted that lifting of the rock shall not occur. Consolidation grouting was done where required to insure the bearing capacity of the rock.

Drainage.—Downstream from the grout curtain a 24-inch half-round drain, bedded in porous concrete at the foundation rock, extends along the spillway, intake, and nonoverflow sections parallel to the axis of the dam and immediately under the drainage gallery. This drain was built in sections, each section acting as a collector drain for three 3½-inch-diameter holes drilled from the floor in the drainage gallery, through the 24-inch drain, and extending 40 feet into the rock foundation. These holes were drilled after all grouting had been completed.

Drainage into the gallery normally flows by gravity to the powerhouse sump, where it is pumped to tailwater. In case the powerhouse sump is not operating, water in the drainage gallery can flow to tailwater through a 12-inch equalization pipe at elevation 863.57. This drain line equalizes uplift pressures with tailwater fluctuations in accordance with the assumptions made in the stability analysis. The equalization pipe is controlled by a valve in the drainage gallery, with an extension stem up to the operating gallery at elevation 898.

To guard against excessive uplift pressure under the comparatively thin apron slabs, a system of 2½-inch drain holes was drilled to a depth of about 10 feet into the rock. The holes were spaced 12 feet on center both in the longitudinal and the transverse direction. Each hole was drilled from the top of the apron through a 3-inch pipe embedded in the slab. After the hole had been drilled the pipe was plugged. A drainage outlet is provided through a 1½-inch pipe

extending from the 3-inch pipe on a 45-degree slope in a downstream direction to the top of apron. This type of drain was selected because the character of the foundation rock at the dam site made it necessary to defer the drilling of drain holes until all foundation grouting near the apron area had been completed.

Apron

The final design of the apron was determined by the condition of the foundation rock and by the hydraulic model studies. The apron slab was divided into blocks to facilitate concrete pouring and to limit shrinkage conditions. The blocks were keyed and doweled to the toe of the spillway and to each other to keep the top surface of the apron in strict alinement. The end sill was built integrally with the apron slabs.

Initial reinforcement designs specified 1¼-inch-square bars spaced on 12- or 8-inch centers. However, because of restrictions on the use of steel, it was necessary to reduce the total tonnage required without endangering the safety of the structures. The top of the slab was, therefore, reinforced with ¾-inch-diameter bars spaced 12 inches on center both ways, using high carbon steel with a minimum yield point of 50,000 pounds per square inch. An exception was made for dowels and bent bars, which were required to be of intermediate or structural grade of 1-inch-diameter minimum size. All bars are placed 5 inches below the top surface.

Training walls

The north and south training walls form continuations of the downstream ends of piers 17 and 28, respectively, and extend to the downstream end of the apron. The sections between the spillway crest and the beginning of the apron consist of 4-foot-thick cantilever walls with the main spillway blocks acting as bases and are reinforced for pressure on the walls when water is discharging over the spillway.

The south training wall is adjacent to and forms part of the concrete lining protecting the steep rock face of the left bank.

The north training wall, which is adjacent to the powerhouse, extends about 88 feet downstream from the draft tube exits and separates the spillway and powerhouse discharges. The downstream portion has an L-shaped cross section and is built in two blocks separated by a contraction joint. The wall is capable of withstanding the differential water pressures, as determined by hydraulic model tests, for various conditions of discharge and tailwater elevations. It is also designed to act as a cofferdam for future unwatering of the vacant stall for the construction and installation of the fourth unit in the powerhouse. For this condition it was assumed that tailwater elevation would be at 892, with the tailrace dry.

Piers

The piers carry the horizontal hydrostatic load transmitted from the spillway gates through the gate anchorages and the vertical load from the operating bridge deck. The 6-foot 6-inch pier thickness required with the radial gate installation effected a saving in over-all spillway length and piers over alternate designs with other type gates because no gate slots are required.

The piers are designed for the following conditions:

1. Gates on either side of pier closed with headwater at elevation 1002.
2. One gate closed, adjacent gate wide open, with headwater at elevation 1002.
3. Emergency bulkhead in one bay, adjacent bay open, with headwater at elevation 1002.
4. One gate closed, emergency bulkhead in adjacent bay, with headwater at elevation 1002.

Condition 4 was found to be the heaviest lateral load condition. All of the conditions, however, are reflected in the reinforcement which was required in the piers. The stress zones and assumed pier restraint for these conditions are shown in figure 19, from which were computed the deflections and stresses in the piers. Piers were reinforced vertically for bending under the lateral loadings. Horizontal reinforcement provides for shrinkage stresses and for distribution of the gate anchorage reactions.

Operating bridge deck

The layout of the spillway deck is the same as for the Cherokee project except for the number of spans. It was largely determined by the operating requirements of the traveling gate hoist, the dogging arrangements, and the clearances required for handling the gates.

The deck was designed as a composite beam consisting of 4¼-inch I-beam bridge flooring, with the spaces between the beams filled with concrete, and a 2-inch concrete finish on top for additional strength and drainage. This slab is supported on three rows of wide-flanged beams spanning between the spillway piers and is cantilevered 3 feet at the upstream side of the deck and 3 feet 9 inches at the downstream side. The track rails for the hoist car, which consist of 3-inch round-edge square bars, are supported directly on top of the bridge flooring. The two downstream rows of deck beams are spaced 7 feet apart to line up with the hoist rails. The upstream deck beam was made the same depth as the track beams to keep the top of the piers at a uniform elevation. Expansion and contraction joints for both the deck slab and its supporting beams were installed at alternate piers. The condition governing the design of the track girder was one in which the hoist was considered as being in a fixed position and supporting the maximum load from the spillway gate. A live load of 150 pounds per square foot was assumed acting on the remainder of the deck slab. Side thrusts from the hoists were considered as transmitted to the spillway piers by the girders.

Gate-dogging supports

A cantilever arrangement of structural steel shapes at the top of each spillway pier supports two gate dogs in adjacent gate openings. It consists of two parallel girders, each composed of an 18-inch channel set vertically and a 10-inch wide-flange beam laid horizontally, the ends of the girders being tied together with a 12-inch channel. This arrangement was found to be more economical and resulted in a simpler framing than connecting the gate-dogging supports into the track beams. The girders are so designed that vertical loads are resisted by the combined section while lateral forces are resisted only by the wide-flange beams. A similar arrangement is provided at the end piers except only one gate dog is supported adjacnet to these piers.

The supports were designed to meet the following loading conditions:

1. A normal dogging load of 60 kips, which is one-half the weight of the gate, using a basic stress of 18,000 pounds per square inch.
2. A maximum dogging load of 120 kips (total weight of one gate), using an allowable stress of 1.25 times the basic stress.
3. A break-down load of 200 kips, with the chain supported by the hoist, using an allowable stress of 29,000 pounds per square inch.

The second condition governed the design of the supports.

Gates

The function of the spillway gates is to regulate and control the discharge of water over the spillway under all conditions of flow. As a wide variety of flow conditions must be met, the spillway gates are arranged for regulating gate openings to avoid unbalanced or concentrated discharges which might lead to serious erosion below the dam or to undesirable cross currents and eddies in the river. An operating sequence designating gates to be opened and amount of opening for the best hydraulic performance was developed by model studies.

The general arrangement of a spillway gate is shown in figure 20. There are 11 gates in the spillway section, each 32 feet high by 40 feet clear distance between spillway piers. Trunnion bearings are so placed as to be out of water during periods of high flow. The top of the gates in their closed position was set at elevation 1002.

The construction of all gates is similar. Each gate consists of a curved steel skin plate stiffened by a series of horizontal beams and supported by a trussed structure made up of five vertical trussed frames, an upper and lower horizontal truss, and two trussed rocker arms that are a continuance of the two end vertical frames. These rocker arms are braced to the horizontal trusses, and their downstream ends are equipped with large lubricated bronze bearings which are supported by and rotate on forged alloy steel trunnion shafts secured to the concrete piers. Rubber seals of the music-note type are bolted to the two sides and to the bottom edges of the upstream face of the skin plate. To prevent the gate from binding between the piers as it is raised or lowered, self-lubricating bronze-bushed rollers are mounted just downstream from the skin plate at the upper and lower corners of the gate. These bear against and roll upon metal surfaces embedded in the concrete piers. Near the lower edge of the upstream face of the skin plate and near the ends of the gate are two structural fastenings for the gate hoist chains. Each gate is equipped with two 1¼-inch-diameter alloy steel die-lock-type hoist chains which lead from the above fastenings up and around the curved skin plate surface to and through the dogging units mounted in the operating deck above. The upper ends of the chains are equipped with special hooks for fastening to the drums of the traveling gate hoists. When the gate is closed or dogged in some open position the excess chains above the dogging units, together with their special hooks, are stored in chain lockers beside the dogging units.

All gates were temporarily assembled in the manufacturer's shops and then disassembled sufficiently to permit shipment by rail. The estimated weight of each gate is 127,000 pounds. All gates are of carbon steel and riveted construction.

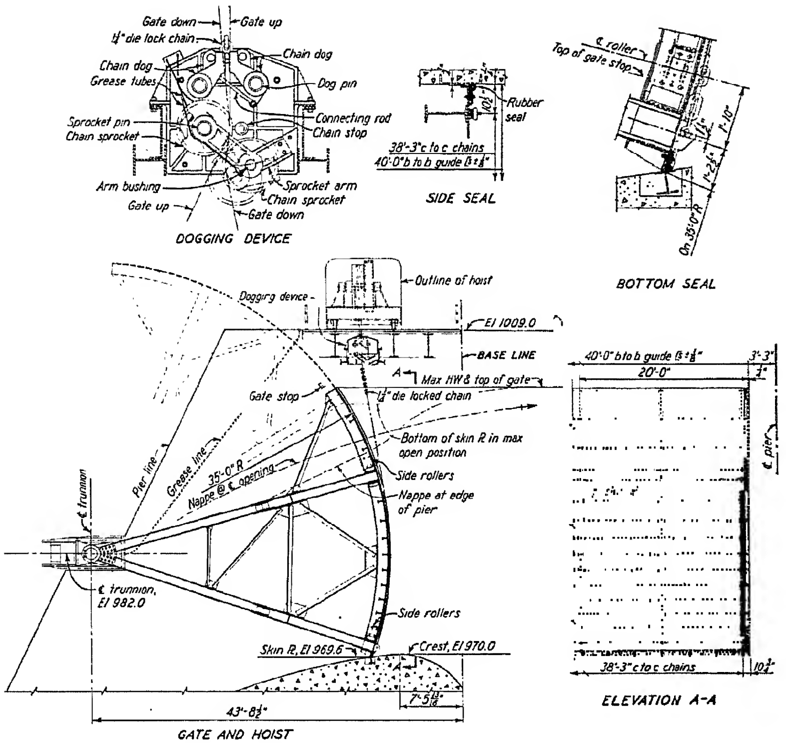


FIGURE 20.—*Spillway gate and dogging device.*

The gates were designed for dead load, functional forces, and a water load on the upstream face of the gate varying from zero at the top of the gate to full hydrostatic head at the bottom, with permissible basic stresses not exceeding 18,000 pounds per square inch. An allowance of $1/16$ inch for corrosion was added to the thickness of all parts of the gate carrying calculated stresses. The horizontal trusses are so arranged in the gate structure that their loads will be equal under maximum gate loading conditions. The gate members are designed also to meet a special load condition resulting from failure of one hoist chain.

Gate anchorage

The thrust from each taintor-gate trunnion is transferred by heavy welded plate members, which project beyond the downstream face of the piers, through eight 4-inch-square steel bars to a welded steel-plate grillage embedded in the piers approximately 24 feet upstream from the center line of the trunnion. Horizontal and vertical bearing plates at the downstream end of the anchorage transmit into the concrete any forces resulting from unbalanced loading. The 4-inch steel bars were wrapped with burlap and painted with asphalt to prevent any bond between the bars and the concrete and to insure transfer of the entire

load directly to the steel-plate grillage. All anchorage assemblies were stress-relieved after completion of shop welding.

To minimize the effect of rotation of the anchorages resulting from unbalanced loading conditions, the anchor bars were prestressed equal to the full water load against the gates by either one of two methods, one being electrical and the other mechanical. A complete description of these methods is covered in chapter 5.

The gate anchorages were designed to meet the following loading conditions:

1. Two adjacent gates in closed position, with headwater level at top of gates at elevation 1002.
2. One gate in closed position, adjacent gate fully raised, with headwater level at elevation 1002.
3. One gate raised approximately 13 feet and adjacent gate in closed position, with headwater level at elevation 1002.

The second condition governed the design of the main members.

Gate-dogging units

Dogging units operating on the hoist chains at approximately the operating deck level are provided to support the gates at varying degrees of spillway gate openings. The units consist of heavy cast-steel frames mounted on structural-steel supports. Between each pair of these frame castings are mounted two pivoted cast-steel chain dogs whose outer ends are shaped to suit the contour of the hoist chain links. Since the dogging units are in a fixed position, the angle of approach of the hoist chains to them varies with the different positions of the gate. For efficient operation of the chain dogs it is essential that the hoist chains lead up approximately vertically between them. To accomplish this at all times, two pocketed cast-steel chain sprockets are mounted below the chain dogs. The upper one of these sprockets functions to drive an indicating device mounted on the outside face of one of the frames. This device indicates in feet the amount of gate opening for all positions of the gate. On the pier side of each of these dogging units there is a locker for storing excess hoist chain. All moving parts are grease-lubricated from points near the operating deck level.

All parts of the dogging units were designed to withstand the vertical and horizontal loads imposed upon them by the hoist chains under the normal operations of raising, lowering, and dogging of gates. The allowable basic stress under these conditions was one-fifth of the ultimate tensile value of the material. Parts of the dogging unit were designed also to meet a possible condition of having to support the gate by one hoist chain only, with a basic stress not to exceed 90 percent of the elastic limit of the material.

Traveling gate hoists

The traveling gate hoists are used to operate the spillway gates. The hoist capacity was determined by the weight and frictional resistance to movement of an individual gate. Two traveling hoists were provided to insure having one in operating condition at all times. Slow hoisting and moderate travel speeds were suitable for this project because regulating operations can be anticipated far enough in advance to allow ample time for gate handling.

Each traveling hoist consists of a structural steel frame and machinery housing mounted on four double-flanged wheels. On the deck of this structural steel frame are mounted the hoisting equipment for lifting a spillway gate and the propelling equipment for driving the hoisting unit along the track on the spillway deck.

The hoisting equipment consists of two drums, one mounted at each end of the structural frame, with provision for manually attaching and detaching hoist chains from the drums. The drums and the slow-speed gear units are mounted on antifriction bearings supported in welded steel side frames. A single electric motor operates this equipment through two worm gear speed reducers and suitable shaft connections.

Near one end of the structural frame and below the deck surface is mounted the propelling equipment. A single electric motor operates this equipment through suitable shaft connections, a high-speed gear set, and a worm gear reducer mounted on one axle only.

Each spillway traveling gate hoist is controlled from a small operating platform on each end where the control switches for the hoist, travel, and power cable reel motors are located. Protective equipment includes overload and undervoltage relays and a manual emergency stop push-button station.

At each end of the frame and to one side of the drums is mounted a manually operated cable hoist for lifting the hoist chain hook and attached chain from storage position to the point of attachment on the drums or for lowering it in the reverse direction.

Spillway sluice gates

The primary purpose of these gates is to provide a means for drawing the reservoir down below the level of the spillway crest in advance of floods. In addition, they may be used to provide additional water discharge in periods of flood. The operating sequence for the best hydraulic performance was determined by hydraulic model tests.

Two gates are installed in tandem in each of the eight sluiceways in the spillway section of the dam (see fig. 21). The upstream gates serve only as emergency gates and normally remain open. The downstream gates are the service gates and are operated either wide open or fully closed. The gates operate under a maximum head of 119 feet above the center of the gate opening, which is at elevation 883. Gate openings are 5 feet 8 inches wide and 10 feet high.

Each gate consists essentially of an upstream and a downstream frame whose interiors conform to the rectangular shape of the adjacent metal sluice liners; a sliding leaf that in closed position seats on sealing surfaces in the downstream frame; and a 24-inch-diameter oil-operated hydraulic hoist mounted directly above the leaf on the bonnet of the gate. The leaf is raised and lowered by the hydraulic hoist which is mounted directly above the bonnet. The piston of this hoist is connected to the leaf by a steel stem and is also fitted with a stem extension that projects up through the top head of the hydraulic cylinder. The upper end of this stem is fitted with a coned head that engages a suspended semiautomatic gate hanger when the gate leaf is in its raised position. This prevents the leaf from drifting down to closed position due to possible leakage of oil past the piston rings. The hooks of the hanger may be released for lower-

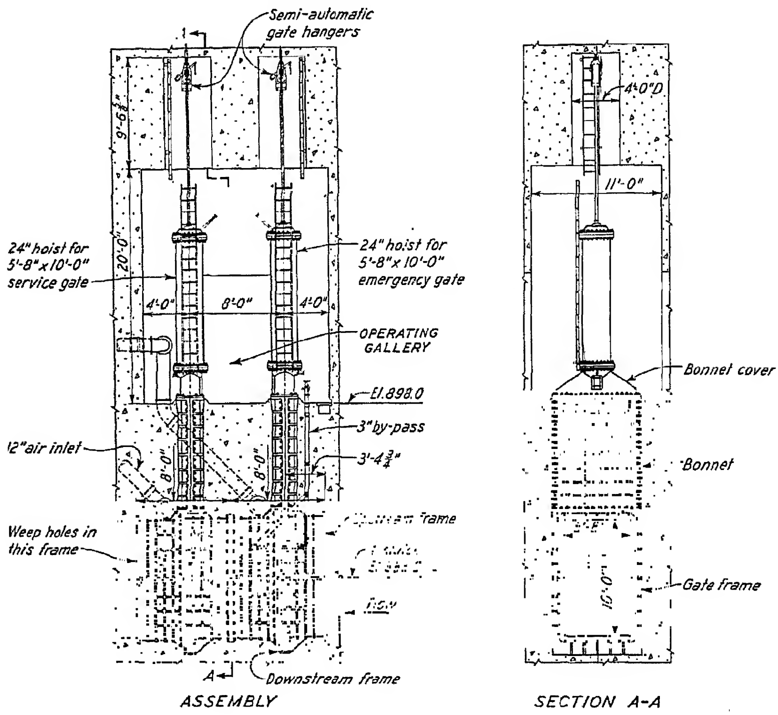


FIGURE 21.—*Spillway sluice gate arrangement.*

ing the gate leaf by the pull exerted by a tension spring and chain after the leaf has been raised sufficiently to take the weight of the moving parts of the gate off these hooks. The coned head is secured to the stem by a safety stud so proportioned that it will break if hydraulic pressure is applied to lower the leaf without first releasing the hanger hooks.

Oil for the operation of the hydraulic hoists is supplied by two pumps having a capacity of 20 gallons per minute at 1,200-pound-per-square-inch working pressure. Only one pump is required for gate operation, the other pump acting as a stand-by unit. The pumps obtain oil from a storage tank located in the pump chamber and having a capacity of 300 gallons. Hydraulic hoists, pumps, and oil storage tank are located at elevation 898 in the operating gallery of the spillway. Valves for control of oil pressure are installed at each individual gate. A local "On—Off—Remote" switch for each oil pump motor and a transfer switch are installed near each motor. Either pump can be selected for remote control from "Start—Stop" push buttons located near each sluice gate. Each set of gates has a 12-inch air inlet and a 3-inch bypass pipe.

The concrete around the frame and bonnet castings is designed to carry all the load, using a design pressure of 1,200 pounds per square inch. The actual working pressure in the hydraulic cylinder is ap-

proximately 1,030 pounds per square inch. A coefficient of friction on bronze sealing seats equals 0.6 at starting.

Sluice liners

The eight sluiceways through the dam are composed of a 5-foot length of entrance section, a 12-foot length of liner plate which connects to the slide gate casting, an 18-foot length of liner plate below the gate casting, and approximately 60 feet of unlined concrete. A steel liner throughout the sluiceway is a very desirable feature, but the need for conserving critical war materials outweighed all other considerations.

The entrance section consists of 1-inch-thick liner plate and ribs with a 2-inch-thick flange for bolting to the steel liner plate. The ¾-inch liner plate is reinforced with structural tees spaced approximately 2 feet on centers. In addition to stiffening the liner plates, the tees also provide adequate anchorage to the concrete and prevent the concrete from shrinking away from the plate.

Trashracks

Original trashrack designs specified mill-fabricated sections; however, because of delay in delivery, temporary trashracks were installed, using available 1¼- and 1½-inch-square reinforcing steel for this purpose. Subsequently, these racks were retained as a permanent feature since their design and operation were considered satisfactory.

Each of the trashracks consists of a series of horizontal trusses spaced 4 feet 6 inches on centers. The upstream chords are curved to a 6-foot 4-inch radius, and attached to them are vertical bars spaced 1 foot 6 inches on centers. The load from the trusses is taken by the stop log guides and distributed to the concrete. The dead weight of the racks is transferred by a number of the vertical bars to bearing plates at the bottom, where the load is distributed to the concrete mass.

The trashracks are designed for a differential head of 5 feet, an allowable working stress of 24,000 pounds per square inch, and a net velocity through the racks of 7.3 feet per second.

For blocks 25, 26, and 27 the racks were modified slightly to make provision for an auxiliary cofferdam for stage 2 construction as a safety measure against possible flooding during the construction of the lower portions of these blocks. This change resulted in the addition of concrete piers for three racks in place of the structural steel stop-log guides and precludes the construction of the upper concrete seat which was originally designed for the permanent rack.

Spillway caisson

For inspection and maintenance of the spillway radial gates it was essential that some provision be made for unwatering the upper sections of the spillway between adjacent piers; to do this with stop-log sections would have required a wide operating deck, some type of traveling crane, and gate slots in each pier. Comparative estimates indicated that it would be more economical to use a caisson or buoyant gate which could be floated into position at the upper end of any spillway opening that is to be sealed off from headwater. Water between the caisson and the spillway gate could then be removed by pumping out with a portable pump or by raising the spillway gate.

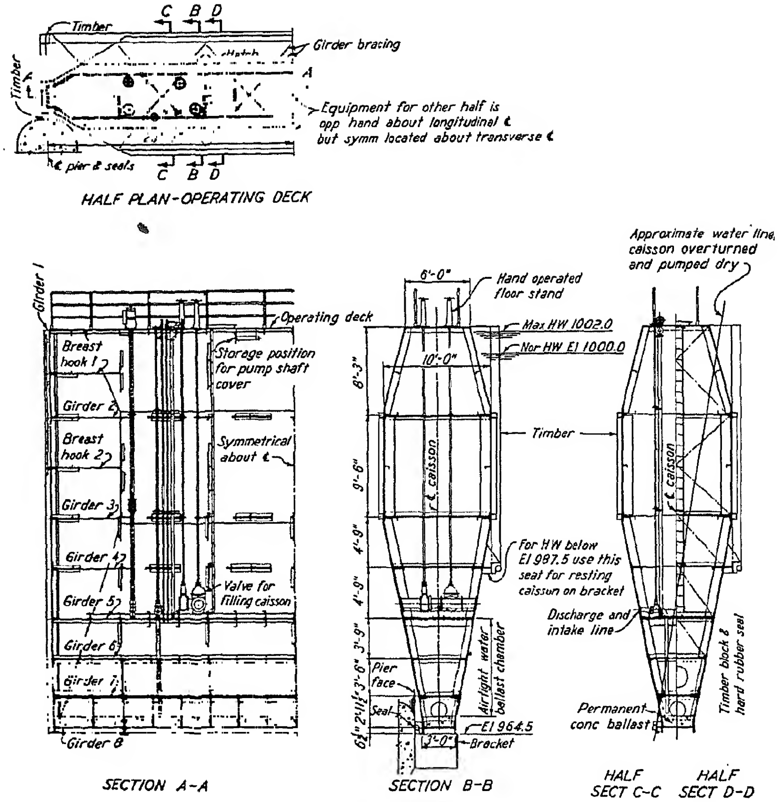


FIGURE 22.—*Spillway caisson.*

The caisson design is essentially a duplicate of the Watts Bar caisson and is the same as for Cherokee. At the time of this publication, only the Watts Bar caisson had been procured. However, the Watts Bar caisson is usable, if the need arises, at Watts Bar, Fort Loudoun, Cherokee, and Douglas.

The caisson (fig. 22) is to be a duplicate of the one designed for the Cherokee spillway. It will be a buoyant vessel approximately 48 feet long, 38 feet deep, and 10 feet wide when in a vertical position for closing a spillway opening. It will consist of a watertight steel shell supported and stiffened on the inside by horizontal girders, vertical trussed frames, and intermediate stiffeners. The horizontal girders are numbered 1 through 8 from top to bottom of caisson. Girder No. 1 will comprise the deck on which will be mounted the pumping equipment, valve controls, and cleats for mooring lines. The caisson will be so shaped and ballasted that it may be careened on its side for its maintenance or for towing to some other project for use. There will be an airtight compartment between horizontal girders Nos. 5 and 8 which will extend the full length of the caisson. In

the bottom there will be placed approximately 20 tons of permanent concrete and steel ballast. The rest of the compartment will be filled with water ballast for normal operation of the caisson in a vertical position. With this permanent concrete, steel, and water ballast in place the center of gravity of the caisson will be kept below the metacenter, and it will be stable under all draft conditions within the prescribed limits. If the caisson is to be careened on its side the water ballast will be blown out by air pressure and the caisson tipped to either side as desired. Additional temporary water ballast can be held above the airtight compartment. Regulation of the draft of the caisson within the prescribed limits will be obtained by filling in or pumping out some of this temporary water ballast. Baffles in the airtight compartment will be constructed with large openings for equalizing and maintenance purposes. Wood and rubber sealing devices are mounted on both sides of the caisson so that either side can be sealed against the upstream face of the spillway to prevent leakage of water into the space between caisson and the spillway gate. Because of possible wide variations in headwater levels, it was necessary to install seals and different points of seating on both faces of caisson for closure of a spillway gate opening. With headwater elevation above 987.5, the caisson will be operated so that the bottom seat will rest on supporting brackets on the face of spillway piers, and the full height of seals will be utilized. When headwater elevation is below elevation 987.5 this seat can no longer be floated over the brackets. It will then be necessary to turn the caisson 180 degrees so that the seat located about 15 feet from the bottom can be brought to rest on the pier brackets. Brackets for storage of the caisson are on the north nonoverflow section.

In designing the caisson, the horizontal girders forming the internal framing are spaced so as to give approximately equal loads upon all except the top and bottom girders. The two bottom girders are rigidly connected by a series of vertical diaphragms and in the final design are treated as a single box girder. Basic unit stress is 16,000 pounds per square inch. A width of skin plate equal to 100 times its thickness is assumed to act as part of the girder flanges.

Electrical system for spillway, intake, and nonoverflow sections

Power.—Duplicate power supply cables for the intake gate hoist, sluice gate, and spillway traveling gate hoist motors assure flexibility and reliability of service. After due consideration was given to the loads, voltage drop, and regulation a supply voltage of 440 volts was selected as the most economical.

Lighting.—Supply for the lighting of the spillway, dam, and embankments is taken from the 440-volt power bus in the gallery at elevation 999 and transformed locally for the multiple and series lighting circuits.

Lighting of the spillway and intake decks is by means of Fresnel lens fixtures located in the upstream handrails. The embankments are lighted by street lighting fixtures with deep pendant hoods and prismatic glass refractors supported on tubular, tapered steel poles with 90-degree curved tops. Lamps rated at 120 volts are used, supplied through series multiple isolating transformers from a 6.6-ampere constant-current system.

Saddle dams Nos. 1 and 3 are lighted by a system similar to that used on the embankments, but the supply is taken from a rural line in that vicinity.

An extensive system of protective floodlighting was installed for the upstream and downstream water approaches to the dam and for the embankments and switchyards. All outdoor lights are normally controlled by a light-sensitive device located on the roof of the elevator tower. They can also be manually controlled from a master switch located in the main control room.

Communications.—Telephones were placed at points on the embankments and in the concrete structures for communication with the central station in the powerhouse.

INTAKE

The intake is a straight gravity-type concrete structure, independently stable of the powerhouse and separated from the powerhouse concrete work by a contraction joint. It consists of four blocks 55 feet 6 inches long, which contain penstocks for supplying water to the hydraulic turbines, and a fifth block acting as a bulkhead section to the service bay area of the powerhouse.

Four 19-foot-diameter steel penstocks are embedded in the mass of the intake structure. The entrances of the penstocks are protected by trashrack structures to stop debris. Three of the penstocks are equipped with gates at the upstream face of the dam, which are operated by hoists and chains from a gallery near the top of the intake section. A bypass pipe and valve system permits filling of the penstock prior to raising the intake gates for turbine operation. The valves for control of this system are located in the operating gallery at elevation 919.4.

A vent in the penstock just below the gate, extending up through the intake to atmosphere, relieves any pressures in the penstock when the gate is closed and the penstock is being unwatered or filled.

The penstocks for the future unit and the deferred unit 2 are temporarily plugged by hemispherical steel bulkheads at the upstream end.

Hydraulic and structural layout

Penstocks are located 61 feet on centers as required for proper concrete embedment for the scroll cases. To minimize the development of transverse cracks caused by temperature and shrinkage effects, it was desirable that the length of the massive concrete blocks be reduced below the 61-foot spacing of the penstocks. A layout was, therefore, developed which permitted reducing this length to 55 feet 6 inches by varying the relationship of the penstocks to the center lines of the intake blocks in which they were embedded. This was accomplished by placing the penstocks for units 1 and 2 at 8 feet 3 inches and 2 feet 9 inches north of their respective center lines, while the penstocks for units 3 and 4 are opposite hand, that is, 2 feet 9 inches and 8 feet 3 inches south of the center lines of their respective blocks. This resulted in a uniform penstock spacing of 61 feet on centers and a uniform intake block 55 feet 6 inches long.

The penstocks are steel lined except at the upstream entrance, which is a concrete transition section from a rectangular opening 14 feet

8 inches wide by 25 feet 0 inch high to the 19-foot 0-inch diameter at the steel pipe lining.

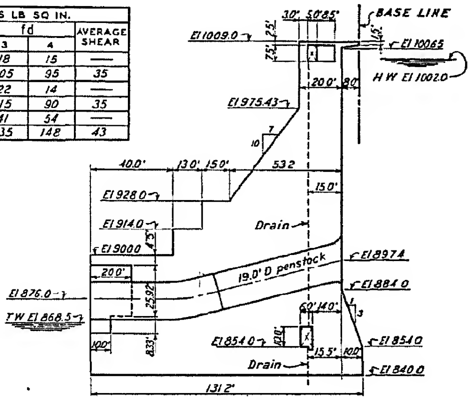
A 20- by 24-foot pit at the lower end of the penstock and adjacent to the powerhouse allows the pipe to "breathe." From the point where the penstock enters the powerhouse concrete to the scroll case its entire circumference is covered with a layer of cork mastic to permit "breathing" and to prevent load transfer between intake and powerhouse structures.

The trashracks were constructed of ample height to keep entrance losses to a minimum and to guard against any possible plugging by debris. On the other hand, storage reservoirs of this type are relatively free of floating drift, and, therefore, it was not considered necessary to install special raking or other rack cleaning facilities.

The decks of the semicircular trashrack structures were set several feet above the minimum expected reservoir draw-down level and are used as a maintenance space for the intake gates. Such maintenance can usually be scheduled during periods of low reservoir level.

EL	CASE NO.	ΣH KIPS	ΣV KIPS	STRESSES LB SQ IN.				
				fu		fd		AVERAGE SHEAR
				1	2	3	4	
876	I	—	57,800	117	120	18	15	—
Units 3&2	II	27,600	48,200	26	36	105	95	35
876	I	—	57,800	114	122	22	14	—
Units 4&1	II	27,600	48,200	18	43	115	90	35
840	I	—	95,400	141	129	41	54	—
	II	45,500	79,360	16	3	135	148	43

Note:
Analyses made for 55.5' length of dam.



INTAKE BLOCK

Figure 23.—*Intake stability analysis.*

The electrical bay and the control room for the powerhouse were economically located in the space available over the toe of the intake blocks, making a convenient and compact powerhouse arrangement.

Stability analysis

The intake blocks are designed to be stable under all conditions of loading without any support from the powerhouse structure. The upper portions of the blocks have the same downstream slope as the nonoverflow sections, that is, 10 on 7.

Two controlling loading conditions were analyzed for base elevations 840 and 876, as follows:

Case 1—Dead load of structure with reservoir empty.
Case 2—Headwater at elevation 1002 and tailwater at elevation 868.5.

The general design assumptions as stated on page 48 were applied to this structure. The results of the analysis made for a 55-foot 6-inch length of dam are shown in figure 23.

Penstocks

Four penstocks, each 19 feet in diameter and approximately 123 feet long, conduct water from the reservoir to the turbines, one penstock for each generating unit. Beginning at the fact of the dam, the penstocks are directed downward on a 3¼ vertical to 12 horizontal slope for a distance of approximately 83 feet to an elbow and then continue horizontally to the scroll case connections. Starting at a point 63 feet 6 inches from the face of the dam, the penstock is lined with a ¾-inch-thick steel plate. The 5-foot upper tangent section and the elbow section have single-butt-strap, double-riveted circumferential joints. The horizontal section to the scroll case has double-riveted lap circumferential joints. All longitudinal joints are double butt strap, quadruple-riveted.

The liner is designed to withstand the full hydrostatic head of 126 feet plus a pressure due to water hammer computed to be equivalent to 30-foot head at the center of the generating units.

The following working stresses were used in the design:

	Pounds per square inch
Tension (net section of plate)	12,000
Shear on rivets (nominal cross section)	10,000
Bearing on rivets (single shear)	20,000
Bearing on rivets (double shear)	24,000

Although liner plates were installed in the upper portion of the penstocks for Cherokee to serve only as liners, similar liners were omitted on this project because of the need for conserving all critical materials possible as an aid to the war effort. At the upstream end of the steel liners for future unit 4 a hemispherical bulkhead consisting of ½-inch plate of riveted and welded construction was installed. The water load against the bulkhead is transmitted into the concrete through a circumferential stiffener ring welded to the liner plate. The bulkhead is riveted to the liner plate.

Because of the uncertainty of intake gate deliveries, additional hemispherical bulkheads were ordered to insure closure of the dam as scheduled. Although the gates were installed prior to closure, it was considered advisable to install a bulkhead in the pen stock for deferred unit 2 as an added precaution against flooding the powerhouse in case of sabotage or accidental lifting of the gate. This bulkhead is fastened to the liner plate by means of fillet and plug welds.

Trashracks

Each penstock intake is surrounded by a semicircular reinforced concrete trashrack structure to protect against the entrance of logs and other large trash which might damage the gates or the turbines. Each structure rests on a reinforced concrete wall which in plan is arranged as four equal chords of a semicircle. The horizontal members are precast reinforced concrete beams connecting to vertical concrete columns spaced about 45 degrees. The precast beams are spaced vertically 15 feet 8 inches on centers with a clear space between the beams of 14 feet 8 inches. Seven-inch channels are embedded in the columns to form slots for the metal trashracks. Four sets of five 13-foot-high by 8-foot-5-inch-wide steel trashracks are provided for each intake passage of the three authorized units only. These racks

are designed for a differential head of 5 feet and a water velocity of 2.4 feet per second based on the net area of the racks.

Intake gates

The function of each of the intake gates is to close its respective penstock opening when it is desired to unwater the penstock for inspection or maintenance of linings and equipment, or in case of an emergency.

The general arrangement of an intake gate and hoist is shown in figure 24. Tractor-type gates, approximately 19 feet 2 inches by 30 feet 3 inches, are installed in the penstock openings of power units 1, 2, and 3. The penstock for unit 4 is temporarily plugged by means of a steel diaphragm, with provision for installation of an intake gate at a future date. Each gate is raised or lowered by an electric-motor-driven fixed hoist and hoist chains. Normally, it is not required to raise or lower an intake gate under unbalanced head pressure. A differential pressure switch in the hoist-motor-control circuit prevents moving the gate from closed position until water pressure on both sides of gate is equalized within close limits. Normal operation of a gate is from the hoist chamber, but for emergency closure a push button is provided on the actuator cabinet in the powerhouse. The gates operate under a maximum head of 105 feet above the centerline of penstock opening. The normal open storage position of a gate is with its top just above the top of the trashrack structure. For general maintenance the gate is raised to clear the top of trashrack structure; there it is removed from the gate guides and blocked out from the face of the dam for repair operations. For repair or replacement of chains, for repair of hoist, or for positioning of gate preparatory to removing through the slot in deck, it must be raised to a position just below the deck. In this position the gate is suspended from the deck by dogging beams and chains provided for that purpose. To lift the gate through the slot in the deck, temporary hoisting equipment must be used.

The structural framing of each intake gate comprises a series of horizontal girders framed at each end into vertical end posts. The skin plate is welded to the downstream face of the gate frame. Two roller trains, one traveling around each end post, extend the entire height of the gate. From normally open position to closed position, the rollers of these trains bear on metal tracks attached to the intake masonry and transmit the water pressure on the upstream side of the gate to the intake structure. When moving upward from normally open position the rollers are inactive and the gate hangs freely in channel guides. To prevent leakage around the gate when in the closed position, a continuous bronze sealing bar is provided along the sides and across the top and bottom of the downstream face of the gate. When the gate is seated these bars are in contact with corrosion-resistant-steel sealing plates attached to the intake structure, being pushed toward the skin plate and held in tight contact with the sealing surfaces by uniformly spaced springs and headwater pressure. The bottom of the gate is shaped to reduce the suction force when closing under unbalanced head.

The design of each gate is the same as for the gates installed at Hiwassee and Cherokee projects, and it was originally made for the former project for 160-foot head. The maximum head at Douglas is 105 feet. The gates were designed for closure under emergency conditions with maximum headwater and the unit operating at full capacity. The maximum downward load for each gate is the combined

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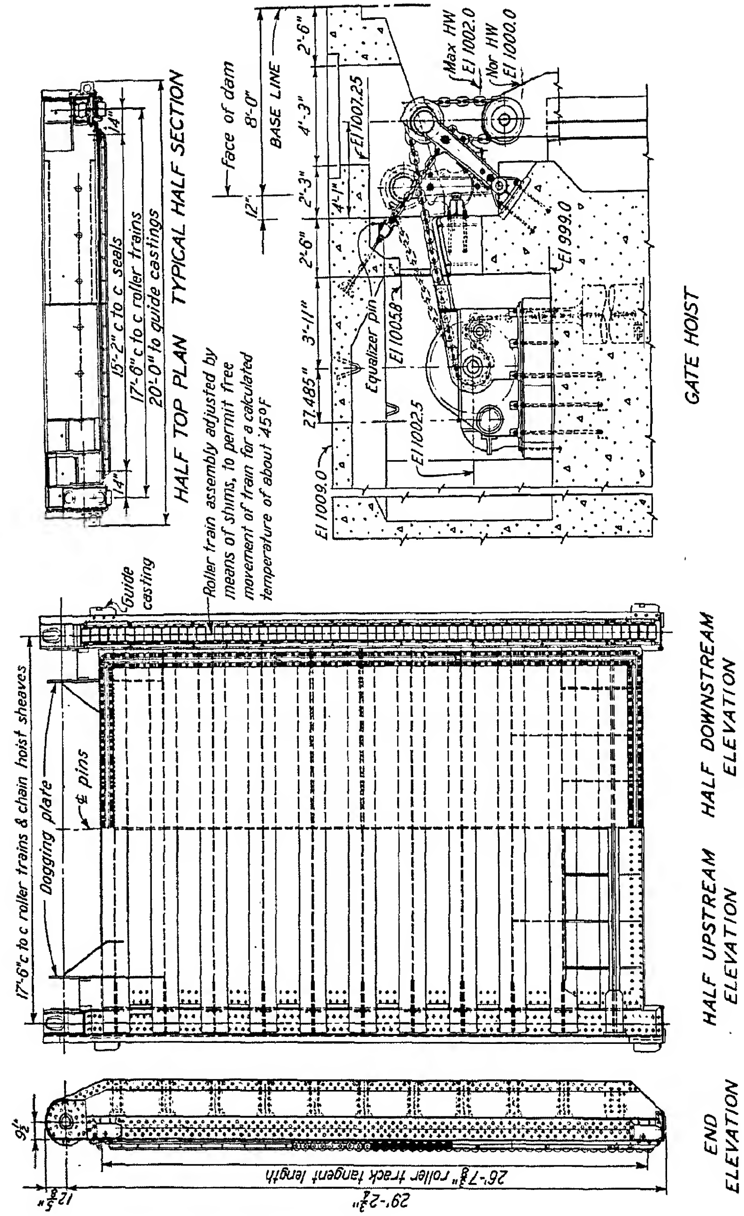


FIGURE 24.—Intake gate and gate hoist arrangement.

weight of gate and chain in water and the maximum suction force acting on the bottom of the gate as it descends across the intake opening. Basic design stresses do not exceed 16,000 pounds per square inch. An allowance of $\frac{1}{16}$ inch for corrosion was added to all parts carrying calculated stresses.

Intake gate hoists

Three hoists are installed in chambers in the dam for handling the intake gates of units 1, 2, and 3. For the future unit 4 only the embedded parts have been installed.

The arrangement for each unit consists of a fixed hoist mounted in a chamber near the top of the dam, two chain booms mounted on the external upstream face of the dam just in front of the hoist chamber, and two hoist chains for connecting the intake gate to the hoist. The fixed hoist consists of a central motor driving two standard reducer units, which in turn drive two specially designed chain hoists that are connected to the gate by the hoist chains. A thrustor-type brake for stopping and holding hoist motion is mounted on each side of the motor adjacent to a reducer unit. Below each chain hoist a well is provided for storing free length of chain.

Each intake gate travels in guides on the upstream face of the dam and is suspended from its hoist by the two hoist chains. One end of each hoist chain is attached to one of the chain booms; it then passes down and around a chain wheel mounted at the top of the gate end post, up and around a chain wheel mounted at outer end of chain boom, through an opening in the upstream wall of the hoist chamber to the chain wheel on the hoist, around and under this chain wheel, over and around an idler in the chain hoist, and down into the chain well. In raising, the excess chain is stored in the chain well; and in lowering, it is withdrawn from it. The hoists are locally controlled by "Raise—Stop—Lower" push-button control switches at the motors and have an emergency "Lower" push-button control switch on the actuator cabinet on the generator room floor. Limit switches on each hoist housing control the gate travel for fully closed position, intake open storage position, upper limit maintenance position, and raised boom position.

A mechanically driven indicator is mounted on one of the chain hoist housings of each fixed hoist unit. A similar indicator is operated by a selsyn transmitter on the hoist and a selsyn receiver in the powerhouse control room. Both indicators show the position of the gate in feet and tenths of a foot above its closed position.

The chain booms are so mounted that they can be withdrawn to a vertical position under the overhang of the intake deck when it is desired to lift the gate up through the opening in the deck.

Maximum load occurs on each hoist when it lowers a gate across a penstock opening for an emergency closure of the penstock under an unbalanced head. This load consists essentially of the weight of gate and hoist chains in water plus the maximum suction force exerted on the bottom of the gate minus the frictional resistances of the gate roller trains and gate-sealing surfaces.

The original hoists were designed to lower a load of 130 net tons at a rate of approximately 8 feet per minute. The maximum raising load

is approximately 60 tons. The normal motor torque was based on the raising load of 60 tons. Design of hoist parts was based on the lowering load of 130 tons, with unit stresses not to exceed one-fifth of the ultimate strength of the materials.

Intake gate guides

The intake gate guides are made up of steel plates formed to provide a slot to guide the intake gate and, below elevation 927.40, to provide a continuous bearing surface for the roller train and intake gate seal.

Below elevation 927.40 a ½-inch structural steel plate is shaped to the desired outline and anchored to the mass concrete of the intake structure by strap anchors. On this plate a 24- by 3-inch steel billet was placed and anchored with bolts which screw into upset hooked rods embedded in the concrete. To the billet plate were welded stain-

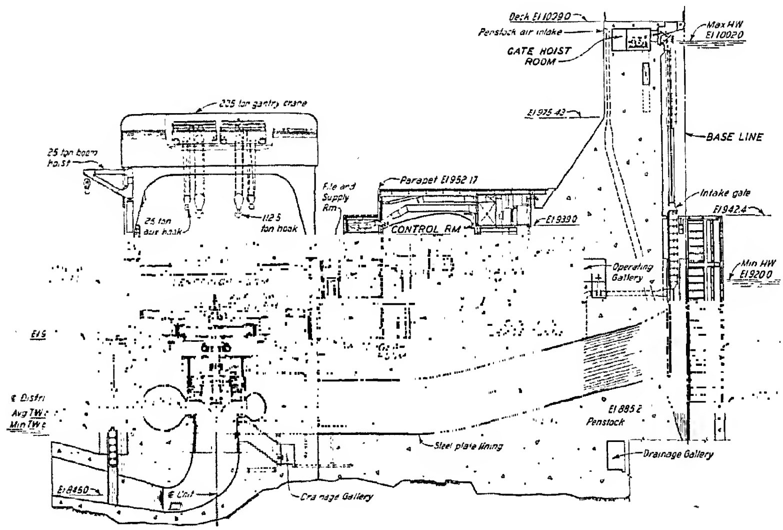


FIGURE 25.—*General section through powerhouse and intake.*

less steel plates which form the running surface for the roller train and the bearing for the gate seal. To permit accurate field adjustment and to insure proper bearing and load distribution, a lead alloy filler metal was poured between the billet and the face of the formed plate.

Above elevation 927.40 the intake gates do not bear against the face of the dam but hang suspended on their chains and are held in alinement by the guides. Between elevations 927.40 and 942.40 this guide is a ½-inch steel plate formed to the desired shape of slot. Between elevation 942.40 and the deck at elevation 999 the slot is formed by a 10- by 4-inch channel weighing 30.2 pounds per foot. Removable sections in the outstanding leg of the channel guide just above the trashrack deck permit the removal of the gate from the guides for maintenance purposes.

POWERHOUSE

The Douglas powerhouse was designed for four generating units. The layout and general design were determined primarily by the equipment requirements, including the construction operations necessary for the placement of the major pieces. Turbine and generator requirements set the generator room floor levels at approximately 19 feet below the maximum design tailwater (see fig. 25). This necessitated enclosing the generator room against such tailwater conditions. Further study favored the semi-outdoor-type powerhouse with a gantry crane mounted on the roof (figs. 25 and 26). For the conditions applying at the site the semi-outdoor powerhouse was more economical and at the same time had certain other advantages in layout and in speeding up the construction operations to meet the emergency nature of this project to produce power for the war effort. The two principal advantages in this connection were:

1. The semioutdoor powerhouse facilitated the placement of embedded parts for the turbines by means of the revolving cranes on the construction trestle which was located over the toe of the intake blocks just upstream from the powerhouse. The higher superstructure walls which would have been required for a fully enclosed type of powerhouse would have interfered with such early placement of the embedded parts.
2. The use of the semioutdoor design made it easy to obtain extra space for the assembly of the generator rotors and other powerhouse equipment by the gantry crane. The crane rails were extended on the riverbank on reinforced concrete girders some 40 feet beyond the regular erection space in and on the roof of the service bay. This additional 40 feet of space available to the crane proved particularly valuable in speeding up the assembly of heavy powerhouse equipment.

It was desirable also to place the access road above maximum expected tailwater, and the layout with the semioutdoor powerhouse combined well with this requirement.

Three generating units were authorized by Congress for the initial installation; but one of these, unit 2, was later deferred. The units are 61 feet on centers, with the service bay located at the north end of the powerhouse. The concrete blocks containing the units, draft tubes, and equipment are separated into individual sections by contraction joints 61 feet on centers. These joints extend from the foundation rock to the roof of the powerhouse.

The electrical bay, control room, and office spaces are conveniently and economically located upstream from the units and over the toe of the intake blocks. The reception room and public spaces were left unfinished during the war emergency to conserve critical materials and are scheduled for completion at a later date.

The electrical bay houses the auxiliary electrical equipment, such as the main low-voltage switch gear and connections, generator neutral equipment, excitation cubicles, and auxiliary power switchboards. This location of equipment encouraged locating the switchyard close to the base of the dam, thus saving in switchyard fill.

The control room, located at the north end of the electrical bay, is approximately centered between the powerhouse equipment and switchyard equipment. The location is economical in use of control cables and convenient for operation.

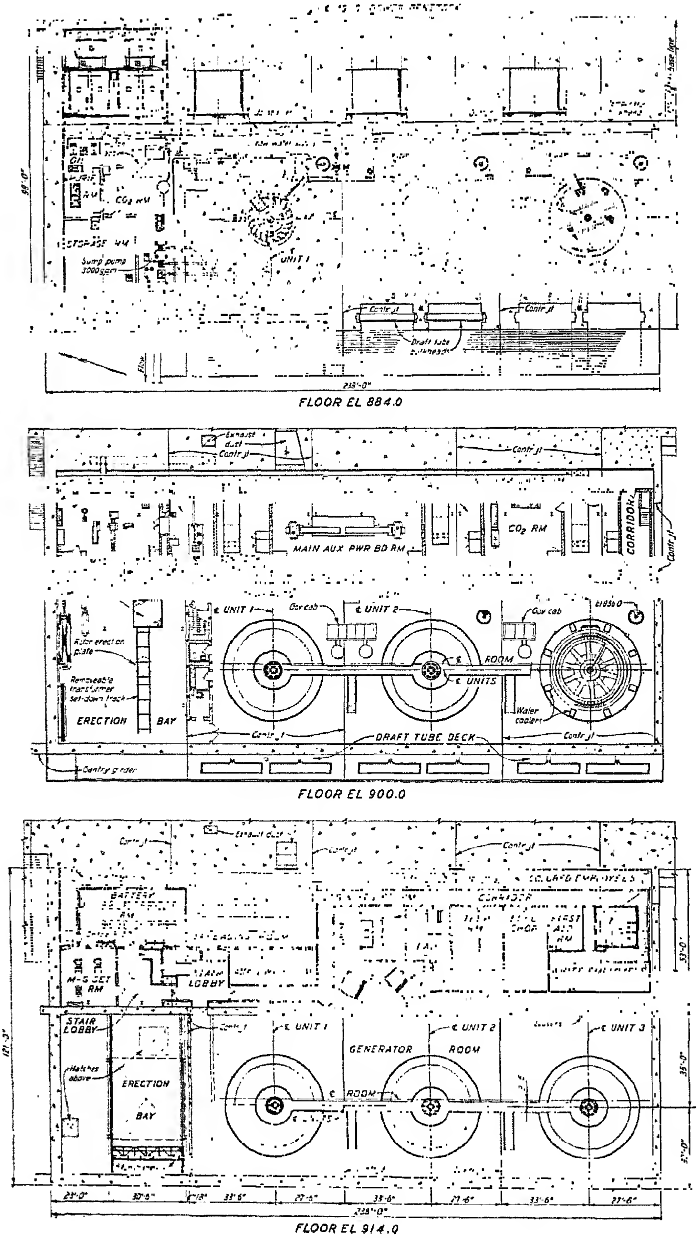
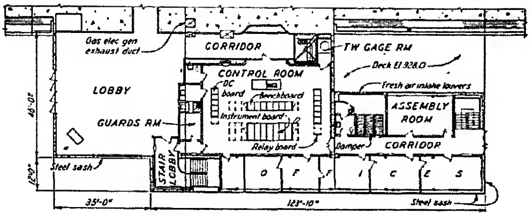
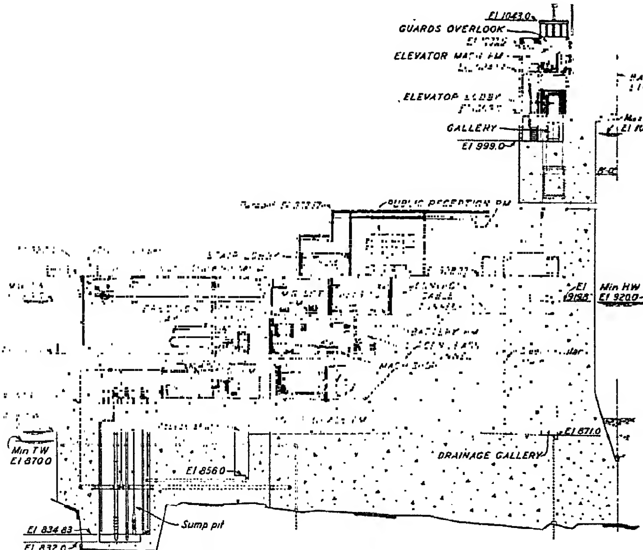


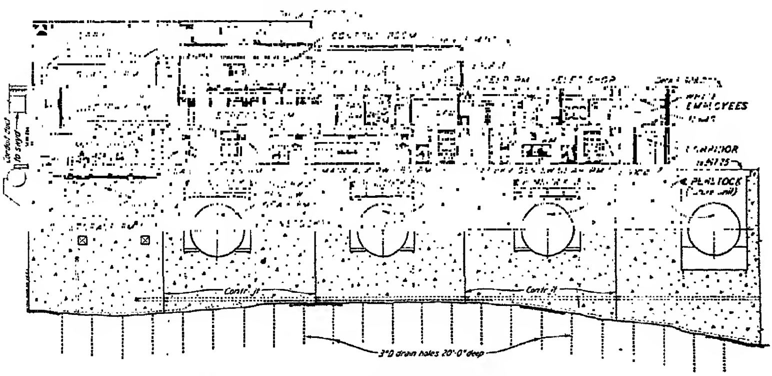
FIGURE 26.—*Powerhouse floor*



FLOOR EL 928.33



TRANSVERSE SECTION THRU SERVICE BAY



LONGITUDINAL SECTION THRU POWERHOUSE, CONTROL BUILDING, AND INTAKE

plans and sections.

The powerhouse service bay contains the necessary erection space and equipment for the maintenance of the plant. In this section is included the machine shop, system drainage sump and accessory pumping equipment, 5-ton service crane, oil storage and purification equipment, air-conditioning equipment, and other similar items.

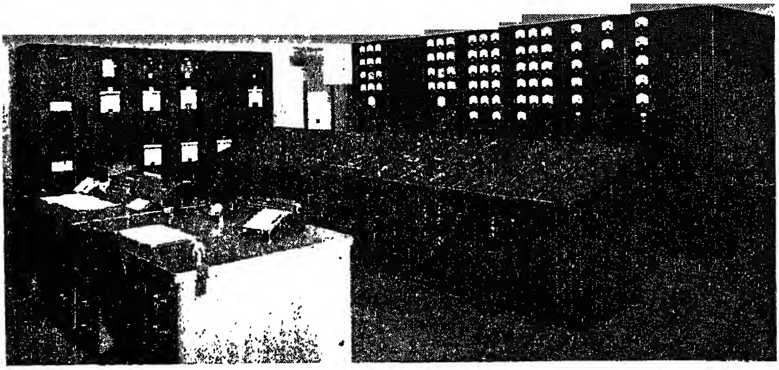


FIGURE 27.—*Control room.*

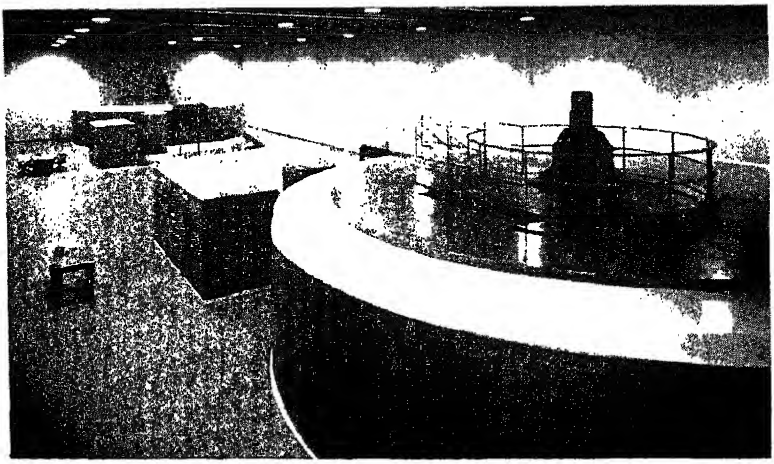


FIGURE 28.—*Generator room.*

UNIT BAY SUBSTRUCTURE

Stability analysis

The stability analyses for the unit bay were made, using the general design assumptions as outlined on page 48. Structurally, the power-

house is a large rectangular block of concrete with water passages through it, and it was analyzed for the following critical design cases:

Case 1—Dead load only, completed structure.

Case 2—Normal operating conditions, with headwater elevation 1002 and tailwater elevation 873.

Case 3—Maximum flood condition, with tailwater elevation 919 and penstock gates closed.

Case 4—Construction condition, with tailwater elevation 919 and the first-stage construction completed. For this condition allowable stresses were increased 50 percent.

The design of reinforcing for the draft tube piers and deck and the superstructure walls was important since these members must transmit heavy loads to the main body of the structure and to the foundation. Stresses in the draft tube piers were computed by the method of "consistent deflections" determined on the basis that the powerhouse loads are carried by a beam with an assumed cross section 22 feet wide by 16 feet deep, comprising the concrete beam between the top of the draft tubes and the lower side of the scroll case. This beam is assumed to distribute the loads to the draft tube piers so that the deflection of the beam is equal to the difference in the shortening of the piers due to the direct load. For deflection calculations the modulus of elasticity of the concrete E_c was assumed as 2,000,000 pounds per square inch, and the modulus of shear in concrete G_c equals 800,000 pounds per square inch.

Draft tubes for units 1, 2, and 3

The draft tube was designed by the turbine manufacturer to fit the unit to be installed. It is a concrete elbow-type draft tube with a 6-foot 0-inch central pier dividing the flow in the downstream section. The roof of the draft tube slopes from the outer wall toward the pier at the center. Figure 29 shows a developed plan and sections of the draft tube.

At the bottom of the runner the draft tube is 16 feet 3 inches in diameter, gradually flaring and changing from circular to rectangular section around the elbow and at the discharge end to a total rectangular opening 40 feet 6 inches wide, with an average height of 14 feet 7¼ inches. At rated capacity, when using 4,420 cubic feet per second at 100-foot head, the discharge velocity is 7.5 feet per second, or 0.895 percent of the rated head.

The upper part of the draft tube, just below the turbine runner, is lined with a ⅝-inch-thick plate-steel liner which extends 16 feet below the center line of the runner. The nose of the pier is also protected with a plate-steel nosing. An access manhole through the steel liner just below the turbine runner provides access for inspection.

In the floor slab of the draft tube and upstream from the draft tube gates three lines of weep holes were placed through the slab to the foundation rock to relieve any uplift pressures which might accumulate there. In addition, two lines of drain holes were drilled a minimum of 8 feet into the foundation rock, with outlets into the draft tube. A line of these holes was placed just upstream from the draft tube gate slots and another at about the low point of the draft tube.

Since the substructure, which contains the draft tubes, is essentially a mass concrete section, it is subject to considerable shrinkage stress.

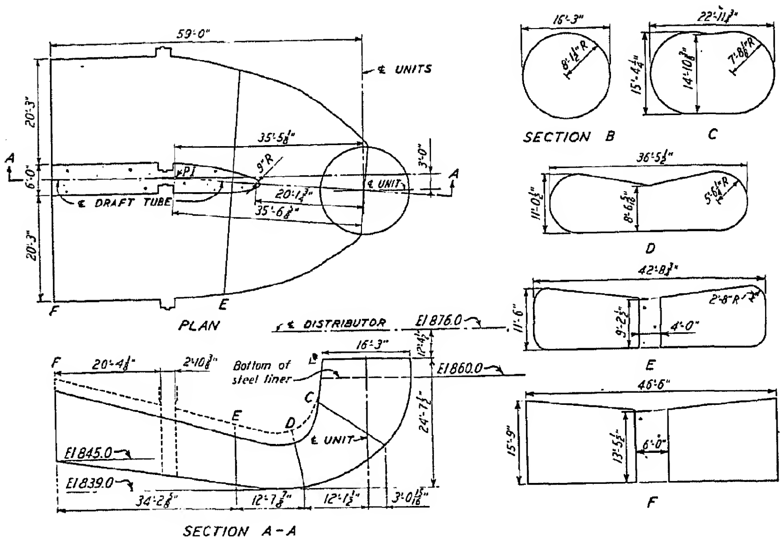


FIGURE 29.—*Draft tube neat lines.*

Two-way reinforcement was, therefore, placed adjacent to all exposed faces in the draft tube. This reinforcement consisted of 1- and 1¼-inch-square bars at 8 to 12 inches on centers and a minimum depth of 5 inches from the face of the concrete. Extra reinforcement was placed in the piers and gate slots as required by the design. The downstream extension of the draft tubes below the gates is a 3-column. 1-story, rigid-frame structure.

Draft tube for unit 4

The draft tube structure for the future unit was constructed complete up to elevation 863, except for a recess provided for the future installation of the steel liner just under the turbine runner. The downstream wall and piers were built complete to the deck at elevation 900. Whenever desired, the temporary draft tube bulkheads can be set in position and the stall unwatered by draining to the powerhouse sump. Adjacent to the spillway, a wall was built up to elevation 900.08 on the top of the draft tube structure to serve as part of the north training wall of the spillway. Figure 30 shows the provisions for the future unit.

Draft tube gates and bulkheads

The function of the draft tube gates is to close off tailwater from the draft tubes and scroll cases during construction and afterward during the operation of the plant whenever it becomes necessary to unwater a unit. The draft tube gates operate under balanced water pressure, the load being applied as the draft tubes are pumped out.

Bulkheads were used during construction to close off tailwater from the draft tubes not closed by draft tube gates and are permanently removed after units are installed. The bulkheads also are operated under balanced water pressure.

Each generating unit has two draft tube passages so that a set of two gates is required to close off one unit. One set of gates is provided for the present installation and may be used to close any draft tube. Additional gates may be secured if the need arises. Three sets of bulkheads were built during construction so that, with the use of a set of gates, the draft tubes of all units could be closed off at the same time. The bulkheads will be further used during the construction of the future units to close off their draft tubes. The gates are approximately 13 feet 5 inches high by 20 feet 3 inches clear opening between piers, and the bulkheads are approximately 13 feet 7¼ inches high by 20 feet 3 inches clear opening between piers.

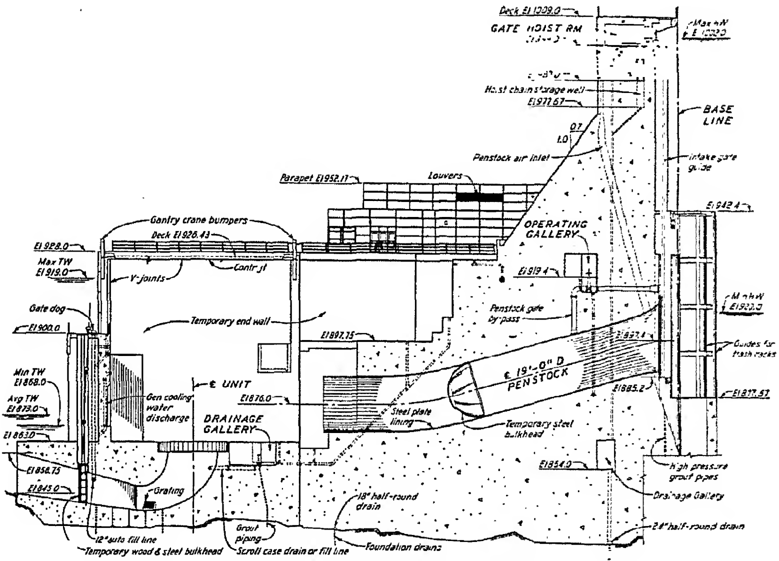


FIGURE 30.—*Section through powerhouse showing provisions for future unit 4.*

The gates and bulkheads operate in slots recessed in the concrete draft tube piers. The slots have embedded steel liners that provide guide, bearing, and sealing surfaces for the gates and bulkheads. Each gate and bulkhead is equipped with a chain sling. The slings are fitted with special links for lifting and dogging. At the draft tube deck level for each opening there is an embedded steel dogging hook over which any of the dogging links may be hooked. In the open position the gates are hung just above the draft tube opening by the chain slings, thus serving as slot fillers. Handling of the gates and bulkheads is by the lifting hook of the 25-ton jib crane mounted on a downstream corner of the powerhouse gantry crane.

The draft tube gates and bulkheads were designed for a water load varying from a head of 45.04 feet at the top to 58.38 feet at the bottom (see fig. 31). The gate slings were tested for a proof load of 89,000 pounds and a breaking load of 178,000 pounds. The bulkhead slings were tested for a proof load of 31,350 pounds and a breaking load of

82,500 pounds. Basic allowable structural design stress for the gates was 18,000 pounds per square inch, with a $\frac{1}{16}$-inch corrosion allowance, and for the bulkheads, 22,500 pounds per square inch, with no allowance for corrosion.

Each gate consists of a downstream vertical skin plate supported by horizontal beams that are framed into two structural end posts. The skin plate is further supported by intermediate vertical stiffener members. Gate water seals are of rubber molded into the form of a music note. With gates in place these seals bear against the surfaces of the embedded slot steel.

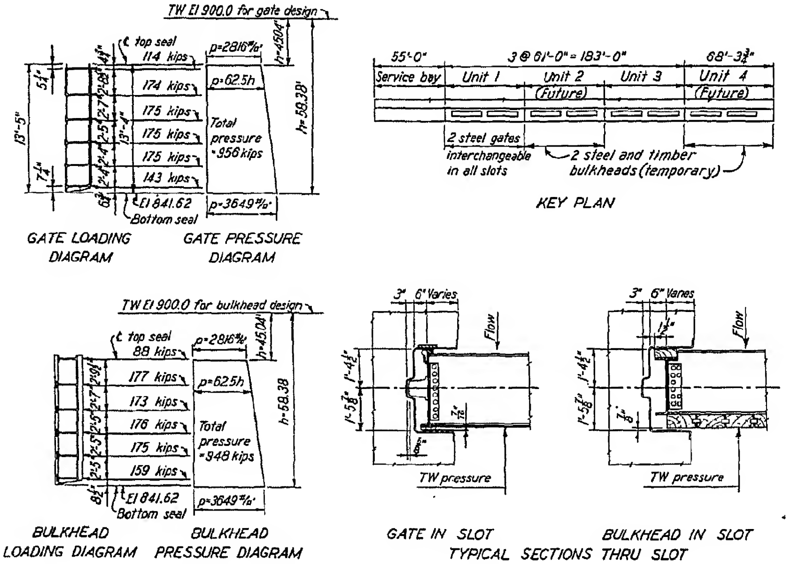


FIGURE 31.—*Draft tube gates and bulkheads—Design.*

Each bulkhead consists of a structural steel frame faced on the downstream side with heavy splined wood lagging. The frame consists of horizontal steel beams framed between two vertical structural end posts and braced with vertical and diagonal angle framing members. Bulkhead water seal members are of wood. With bulkheads in place they bear against the surfaces of the embedded slot steel.

Scroll cases for units 1 and 3

The scroll cases are the riveted plate-steel type, having an inlet diameter of 19 feet 0 inch with a maximum plate thickness of $1\frac{7}{16}$ inches, reducing at the smaller end of the casing to a minimum of $\frac{7}{8}$ inch in thickness. The circumferential joints are double-lap riveted; and the longitudinal joints, where more than one plate is required to complete the circumference, are triple-riveted lap construction. The steel used in the scroll case is ASTM A–70039 with 0.25 to 0.30 percent carbon, having an ultimate strength of 55,000 to 65,000 pounds per square inch and a yield point of not less than 50 percent of the ultimate strength.

Based on the contract performance guaranties, the velocity of water in the penstock and scroll case entrance is 15.6 feet per second when using 4,420 cubic feet per second at rated capacity. This is equivalent to 3.8 feet of head, or 19½ percent of the spouting velocity at rated head.

The scroll cases are encased in the mass concrete of the powerhouse substructure. A layer of cork-tar mastic was placed over the upper two-thirds of the circumference of the scroll cases to permit expansion and contraction of the steel plate without transmitting stress to the concrete. This material consisted of a ⅜-inch-thick troweled layer of a mixture of tar and ground cork applied over a brush prime coat of the same tar and covered after application with cotton canvas. At the lower extremes of this mastic a porous concrete fillet was placed, leading to a drain pipe to carry away any leakage. The mastic was only placed over the inlet part of the scroll and around 144 degrees from the longitudinal center line of the units. No mastic was required at the small end of the scroll case because of better supporting conditions.

The scroll cases are designed to take the headwater pressures on the unit, and with the mastic filler around the cases only a relatively small portion of these stresses will be transferred to the concrete encasement. It was not necessary, therefore, to provide reinforcement around the scroll cases except in the thin sections between the scroll case and the turbine pit liner and over that portion of the scroll cases which was not covered by the mastic expansion material. A layer of porous concrete and drain lines below the generator room floor between the structural concrete and the electrical fill intercepts any leakage that might come from the scroll case through shrinkage cracks in the surrounding concrete.

The upstream wall of the powerhouse required special design considerations. It was desired to carry the walls up to finished grade to permit the use of the powerhouse gantry crane as soon as possible and before concreting in the embedded steel parts of the turbine and generator. A heavily reinforced wall was, therefore, constructed to support the crane.

Care was required in the placement of reinforcement around the generator leads. The minimum distance between the center line of the nearest reinforcement bar and the center line of generator lead was specified to be 9 inches. This distance is, of course, determined by the amount of current carried in the leads. In addition also, any complete looping of steel around a single generator lead was avoided because the induced currents set up would heat up both the generator leads and the reinforcing bars, with detrimental effect.

Scroll case for unit 2

Since the installation of the turbine and generator, with associated equipment, for unit 2 was deferred, it was necessary to make provisions for the later installation of the turbine scroll case, curb and speed rings, and all other embedded metal parts above the draft tube liner. Unlike the future unit 4, unit 2 is in the enclosed portions of the powerhouse; and, therefore, the downstream wall was required to withstand tailwater to elevation 919. Also, with the top of concrete in unit 2 partially at elevation 863 and partially at elevation 866

and that of the adjacent units 1 and 3 at elevation 900, there was a resultant lateral thrust which had to be considered for the stability of units 1 and 3. It was found that this condition resulted in only a small tension in one corner of unit 3. Extra reinforcement was added in the downstream wall of unit 2, and the haunches near the scroll case were increased to the greatest extent possible without curtailing erection clearance around the scroll case.

The stall was covered by wood flooring, designed for a uniform load of 100 pounds per square foot and supported on wooden trusses. Finished elevation is the same as the rest of the generator room to remove the hazard of a large open pit between units 1 and 3 and at the same time improve the appearance of the generator room. A plan and section of the temporary construction in unit 2 stall are shown in figure 32.

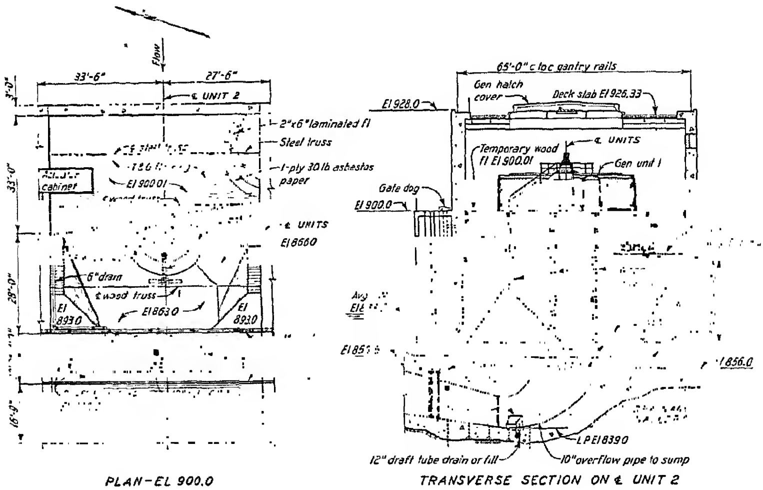


FIGURE 32.—*Plan and section of temporary construction in unit 2 stall.*

SERVICE BAY SUBSTRUCTURE

No major design problems were encountered in the service bay substructure. The rock was excavated to give a uniform base slab thickness of about 19 feet. This resulted in a structure safe against buoyancy and overturning. The massive concrete base extends from the foundation up to elevation 884. Above elevation 884 heavy structural concrete walls are required to withstand the earth and water pressures from the outside as well as to carry the loads from 225-ton gantry crane.

Adjacent to the first unit, a shaft was built with bottom at elevation 832 to serve as the sump for the powerhouse and dam. The walls were made 4 and 6 feet thick and reinforced for water pressure and shrinkage. Shrinkage reinforcement was also placed in the faces of all vertical shafts, over the roofs of all horizontal shafts and ducts in the mass concrete, and in the faces of the substructure walls.

The service bay was analyzed for stability under the following critical conditions of load:

Case 1—Dead load only.
Case 2—Dry backfill around exterior walls.
Case 3—Normal operating condition, with tailwater elevation 873.
Case 4—Flood operating condition, with tailwater elevation 919. For this condition the allowable stresses for reinforced sections were increased 50 percent.

The service bay must act as a retaining wall for the materials at the riverbank as well as the surcharge loads applied when the heavy equipment was assembled in the erection space under the gantry crane. A differential water pressure must also be considered because a seal was placed in the joint between the service bay and unit 1 at elevation 888, dropping to elevation 871 in the joint between the service bay and intake, and any tailwater above these elevations will build up differential hydrostatic pressures in either or both directions. The horizontal thrust of the gantry crane must also be included.

POWERHOUSE SUPERSTRUCTURE

The term "superstructure" includes the generator room and service bay walls, all floors carried on steel framing, and the skeleton walls of the electrical bay and control room.

Generator room and service bay

The superstructure walls above the generator room floor, elevation 900, were required to carry the loads from the 225-ton gantry and to protect against tailwater elevation 919. These walls were constructed as heavy reinforced concrete sections to elevation 928, the roof of the generator room. The downstream wall is a 4-foot-thick wall designed as a cantilever to withstand tailwater to elevation 919 which must also support the rolling load of the gantry crane. The critical design load from the gantry is shown in figure 33. The gantry truckload is distributed over four wheels and includes dead load, live load, impact as 10 percent of the live load, traction load, and a wind load of 10 pounds per square foot on the crane, with components of each force acting vertically and horizontally.

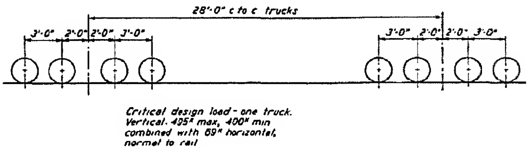


FIGURE 33.—*Gantry crane loading for powerhouse wall design.*

The upstream wall is 3 feet thick and is designed to carry the same gantry loads as the downstream wall, but is not required to withstand tailwater pressures. Special design and extra reinforcement were required, where openings through the wall occurred, to carry the heavy crane loads.

The roof is built with conventional structural steel framing, the steel members being supported on the concrete walls. A large hatch opening is provided through the roof over the center of each unit for

handling major pieces of equipment with the gantry crane. The hatch covers are constructed of structural members and steel plates. The roof is fabricated from precast concrete slabs carried on the structural steel framing. These slabs are covered with a built-up roofing which, in turn, is protected by another layer of precast concrete slabs, approximately 2 feet 6 inches square, selected to serve as a wearing surface and to give a pleasing architectural finish.

The structural steel framing supporting the roof is tied into the concrete walls, thus giving additional support at the top of these sections. Although the walls were designed as cantilevers, the support given by the roof beams required study to determine whether the proper amount of reinforcing steel had been placed in the walls to take any loads which might be imposed by such construction. This condition did affect slightly the required reinforcement.

The contraction joints between the units were carried up through the walls and continued through the roof by placing beams on either side of the joint, encasing them in concrete and placing a seal between the concrete encased beams. The roof flashing was also tied into this concrete.

The erection bay at elevation 900 and the deck over the service bay are designed for a live load of 1,000 pounds per square foot. The roof over the generator room is designed for a live load of 200 pounds per square foot.

Electrical bay and control room

For that portion of the powerhouse superstructure which is located over the toe of the intake section, including the electrical bay and office spaces, conventional structural steel framing supports structural concrete floors and precast concrete roof slabs. The interior partitions and walls are principally tile or concrete brick. The contraction joint and filler between the powerhouse and the intake mass concrete sections are carried up through the superstructure, since deflections of the intake structure under reservoir water loads will, of course, be reflected here as well.

Transverse contraction joints through this portion of the powerhouse superstructure were made to match the joints in the intake structure. These joints were made continuous through the walls, floors, and roof slabs by double columns and double floor beams, placing one on either side of each joint.

The floors of the machine shop and electric shop are designed for a live load of 400 pounds per square foot, while the floors of other equipment rooms are designed for a live load of 200 pounds per square foot. The floors of the lobby, office spaces, toilet and locker rooms, terminal room, control room, and other miscellaneous rooms are designed for a live load of 100 pounds per square foot. The roof over the office spaces and electrical bay is designed for a live load of 50 pounds per square foot. The deck at elevation 928 over the telephone room and the floor of the electric shop are designed for a live load of 250 pounds per square foot or standard H–20 loading, whichever is greater.

Architectural treatment

While the major features of the powerhouse were designed to meet engineering requirements, the details were influenced by a considera-

tion for uniformity of appearance with the other elements of the project and a desire to express their function in a simple forthright manner. In the design of the control building, some leeway was allowed for architectural expression in that a large part of the structure is devoted to visitors' facilities and offices, the size and location of which were not fixed by the plant layout.

With the powerhouse overshadowed by the massive structure of the dam, the prime consideration was that of establishing a suitable scale. A massive appearance was necessary for the walls, and the building should appear as a smaller block of concrete appended to the dam. This was accomplished by making all walls of concrete and by dividing the surfaces into large areas through the use of V-grooves at the construction and contraction joints, similar to the jointing in the dam itself. The addition of square concrete deck slabs over the roofing in the deck of the powerhouse and on the roof of the control building helped materially in carrying out this effect. No effort was made to obtain any special finish on the exterior walls of the powerhouse, but the use of absorptive form lining on the walls of the control building added to the appearance of this building.

The height of the control building was determined principally by the necessary height of ceiling in the control room and the visitors' reception room. By extending the higher roof over these two areas, sufficient room was added in the attic space to house the public toilets and the air-conditioning equipment. The remainder of the building, containing only the offices and corridors, could be made somewhat lower, with the office wing folding around the higher section.

Designs were completed for the visitors' reception room, rest rooms, and toilets, but because of the scarcity of labor and certain critical materials, completion of the interior of these areas was deferred until after the war. The proposed layout includes access from the reception room to the elevator in the dam and a short corridor to a window which allows visitors to see into the control room.

In the control room an accoustical tile ceiling follows the line of an asymmetrical curve in order to deflect the rays of the battery of lights behind the operator and to secure indirect lighting of varying intensity without causing undesirable reflections on the instrument faces. Dull gray walls and a blue linoleum tile floor are also used for elimination of unnecessary strain on the eyes of the operators.

The offices are arranged in a row along the downstream side of the building with an unbroken line of windows; they get the maximum amount of daylight. They are quite conventional in character and are conveniently arranged with respect to the control room and other areas in the plant. The employees' toilets and locker rooms follow closely the type used on other projects, with walls of light-blue glazed tile and floors of reddish-brown terrazzo.

The improbability of condensation of moisture on the walls of the generator room made it unnecessary to consider the use of a glazed tile or other lining. Since the red ceramic tile floor was the only fixed color in the room, the other colors were selected to blend with it. The walls were painted concrete color; the exposed steel was painted blue-gray; and the generators, actuator cabinets, and pressure tanks were painted blue with yellow trim.

Motors are rated 440 volts, 3 phase, 60 cycles, with characteristics to

suit the particular operation required of each motor. Motors are equipped with shoe-type brakes of the rated-torque type.

Power is supplied through a cable on a weatherproof reel which is mounted on a sill member at the west end of the crane. The cable is 115 feet long, No. 4/0, 3-conductor, rubber-covered. At its outer end is a power plug suitable for plugging into power receptacles spaced approximately 146 feet apart in the operating deck. To keep payout of the conductor cable within safe limits of its length, an alarm bell on the reel rings when approximately 75 feet of cable is unreeled, and a limit switch automatically cuts off power to the crane when 83 feet of cable is unreeled.

Controls are located in the operator's cab and are so arranged that one man can control all movements of the crane. Controls for all crane motors are of the full-magnetic, reversing, time-limiting, acceleration type, operated by master switches. They are designated to limit the vertical movement of the main hooks to 1/16 inch, when starting from rest, and to limit the movement of the auxiliary hooks, the trolley and gantry travels, and the jib-boom slewing to 1/4 inch, when starting from rest. Controls are so arranged that the operation of the crane travel, the trolley travel, and the hook hoist is limited to one motion at a time.

TURBINES AND GOVERNORS

The hydraulic turbines are the vertical-shaft, plate-steel, spiral-case type and the governors are the cabinet-actuator type, a twin cabinet housing the equipment for units 1 and 2 and a single cabinet housing the equipment for unit 3.

Turbines

The turbines are rated at 41,500 horsepower, 100-foot head, 94.7 revolutions per minute. While this speed gives a relatively low specific speed for a normal head of 100 feet, the runner was selected so as to be safe against cavitation and vibration when operating under the maximum head of 130 feet. The speed was selected so that the runner would develop best efficiency when operating under about 110-foot net head.

Turbine details.—A cast-steel speed ring forms the main foundation ring for the turbine, and the 20 stay vanes act as vertical columns to transmit to the foundation the weight of the structures and equipment above. The scroll case is riveted to the speed ring at its periphery.

The runner is a 1-piece casting with 15 blades. The inlet diameter is 165 inches and the throat diameter is 171 inches. The runner is bolted to the turbine shaft, which has a diameter of 33 inches and a length of 12 feet 6 7/8 inches. The main shaft is a mild-steel forging with flanges at both ends—the upper flange for bolting to the generator shaft and the lower flange for bolting to the runner.

The turbine shaft is guided in a babbitt-lined, oil-lubricated bearing having a diameter of 33 1/2 inches. A chromium steel corrosion-resistant sleeve, 33 1/2 inches in diameter by 11 1/2 inches high, protects the shaft where it passes through a packing box at the head cover. The

lubricating oil for the turbine bearing is circulated by a motor-driven pump which draws the oil from a small reservoir located in a recess in the turbine pit and delivers it through a fine strainer to a chamber in the upper part of the bearing. From the chamber it flows by gravity to lubricate and cool the bearing. The main circulating pump is driven by a 440-volt, 60-cycle, 3-phase, alternating-current motor. The normal pump pressure is approximately 15 pounds per square inch. In case of failure of the station-service supply, a flow-indicator and pressure-control device closes contacts, causing an alarm to ring on the governor board and starting an auxiliary circulating pump driven from the 250-volt storage-battery supply. No cooling coils are required to cool the oil, because the amount of heat generated by the bearing is slight. Resistance-type thermocouples are embedded in the bearing, and a record of their temperatures is printed continuously on an instrument on the governor panel. A bulb-type remote-indicating thermometer is also embedded in one section of the bearing, and the indicator, mounted on the governor actuator, is equipped with a contact which causes an alarm to sound in case of high temperatures.

Twenty cast-steel wicket gates control the flow of water to the turbine runner. The amount of water admitted to the turbine is controlled by the two servomotors through a central shifting ring which is connected to the upper end of each gate by a link-and-pin mechanism. In each gate connection a shearing pin protects the mechanism in case a foreign object becomes wedged between the gates. An eccentrically turned pin in each mechanism permits individual adjustment to secure proper seating of each gate in the closed position.

The unit is set with the center line of the runner at elevation 876, and since the normal tailwater is approximately elevation 873 when two units are operating, or nearly elevation 870 with no flow through the powerhouse, the runner spins free of tailwater. When motored for power factor correction, or as an operating reserve to come on the line in case of emergency, the only loss in the unit is the energy required to spin the generator plus the windage and friction losses in the revolving parts. This amounts to about 640 kilowatts. An air valve admits air to the turbine when it is operating at light loads or during periods of motoring. The position of the air valve is controlled by a linkage connected to the guide vane mechanism. Tests indicated that the valve should start to open at about 45-percent gate opening. Other tests conducted with this air valve, both open and closed, indicated that at light loads the admission of air to the space around the runner resulted in an increased production of nearly 2,000 kilowatts. For gate openings above 45 percent, the admission of air would cause a slight decrease in the output of the turbine.

Field tests—While no water measurements have been made to determine the exact efficiency of the units, index tests and capacity tests have been conducted to determine the output of the units and to determine the shape of the efficiency curves. Figure 34 shows the performance curves from a minimum head of 55 feet to a maximum head of 145 feet. Tests indicate that the turbines exceed their capacity guaranties by about 11 percent. At any head above 100 feet, the turbine output is limited by the 33,333 kilovolt-ampere rating of the generator. For heads above 112 feet, the 80° rating of the generator, 38,333

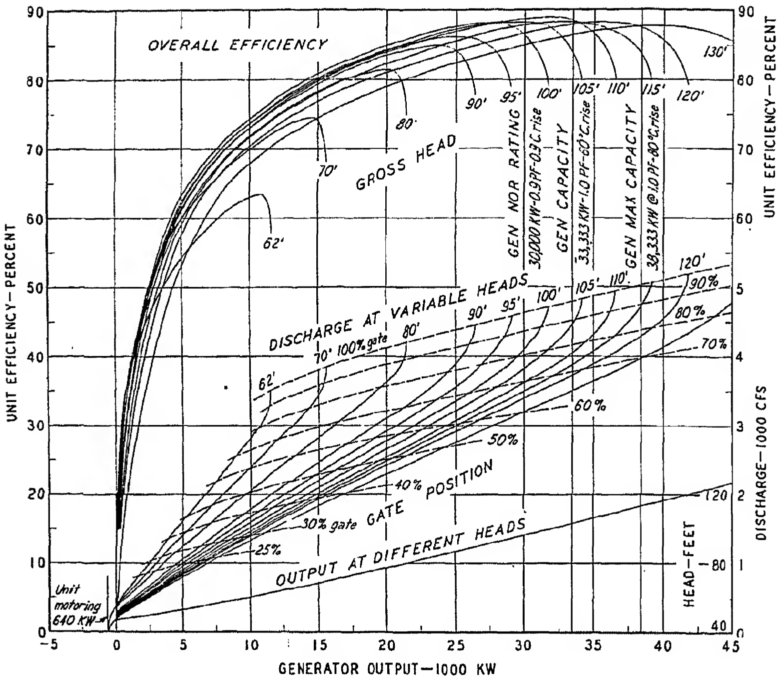


FIGURE 34.—*Performance curves for Douglas units.*

kilovolt-amperes at 100-percent power factor, can be exceeded at full gate opening.

There are two methods of limiting the turbine gate opening to prevent excess load on the generator during periods of high head. A mechanical block is fastened to one of the guide vane cylinders; this block can be adjusted to limit the maximum guide vane opening to approximately 60 percent of full opening. The adjustment on the block is changed gradually as the head changes. The second method consists of a gate limit control on the governor; this control can be set to limit the maximum gate opening to any value between zero and full gate.

Governors

A twin actuator cabinet was provided for units 1 and 2 and a single actuator cabinet for unit 3. These enclosures contain all the essential elements for the governors. Each of the two sets of equipment in the double cabinet includes a 150-gallon-per-minute, 300-pound-per-square-inch-pressure oil pump driven by a 40-horsepower motor, a governor control column on which is mounted the motor-driven fly-balls and the control panels, a main governor relay valve and pilot valve, shut-off valves and hand control valves, auxiliary pressure switches, and other controls. The combined oil sump tank for units 1 and 2 is in the lower part of the cabinet. It has a partition with

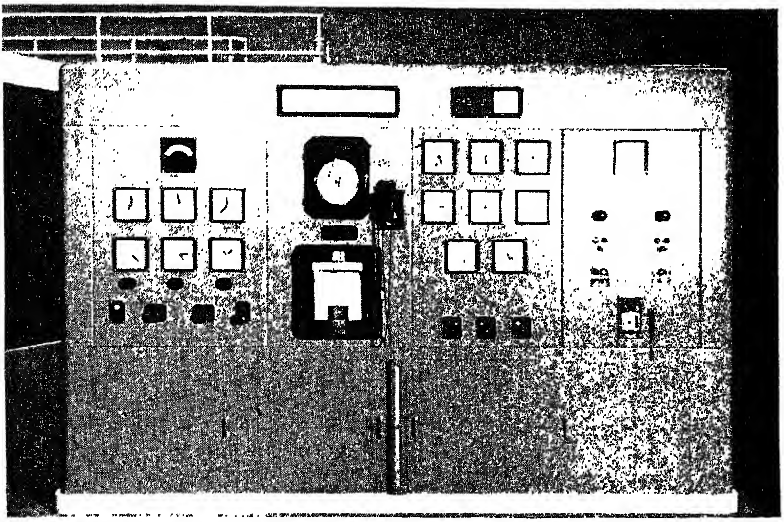


FIGURE 35.—*Governor cabinet.*

isolating valves so that the sump for either governor can be operated separately. Units 1 and 2 also have interconnected oil pressure systems which enable both governors to be operated from one pump. The unit 3 governor is entirely separate (see fig. 35). Two 150-gallon-per-minute pumps, one of which is a stand-by, supply oil for this unit.

One pressure tank for each unit is located behind the actuator on the generator room floor. The volume of each pressure tank is 172 cubic feet, of which 43 cubic feet is usable oil. The air cushion on the oil pressure tanks is maintained by a small motor-driven air compressor of 8-cubic-foot-per-minute capacity and 300-pound-per-square-inch pressure. The compressor is mounted in the lower gallery, and piping is arranged to supply all three pressure tanks.

The bore of the guide vane cylinders is 22 inches, the stroke is 18.625 inches, and the piston rod is 6 inches in diameter. For a net stroke of the two guide vane servomotors in one direction, the volume of oil displaced is 13,640 cubic inches. Five-inch pipes are used for the main oil supply lines.

The generator brakes are controlled by a small air brake valve mounted on the actuator. The operation is entirely manual, and the valve is three-way, with a pressure switch connected to the brake cylinder line. An alarm sounds if the brakes are applied when the unit is operating under load.

GENERATORS AND AUXILIARIES

Generators

The generator rating and capacity were selected to match the turbine output at normal and maximum heads. The turbine has a rated output, at rated head and best gate, of 41,500 horsepower, and at maximum head and full gate, 50,000 horsepower. Corresponding generator outputs, with efficiency of about 97 percent, are 30,000 and

36,000 kilowatts. Each generator was therefore rated at 30,000 kilowatts, continuous at 60° centigrade rise and, with normal design, has a capacity of 34,500 kilowatts continuous at 80° centigrade rise. It will therefore operate most of the time at 60° centigrade rise which is conservative for its type B insulation, and under the infrequent high head conditions, it can carry the maximum the turbine can deliver without serious reduction of life expectancy. System conditions justified a 0.9 power factor, and each generator is rated 33,333 kilovolt-amperes, 13.8 kilovolts, 3 phase, 60 cycles, 60° centigrade rise about 40° centigrade ambient air, 94.7 revolutions per minute. The turbine and generator arrangement is shown in figure 36.

Each generator is the vertical water-wheel-driven type with combination Kingsbury-type thrust and segmental guide bearing located below the rotor. The generator is totally enclosed, air-cooled, with water-cooled heat exchangers within the housing.

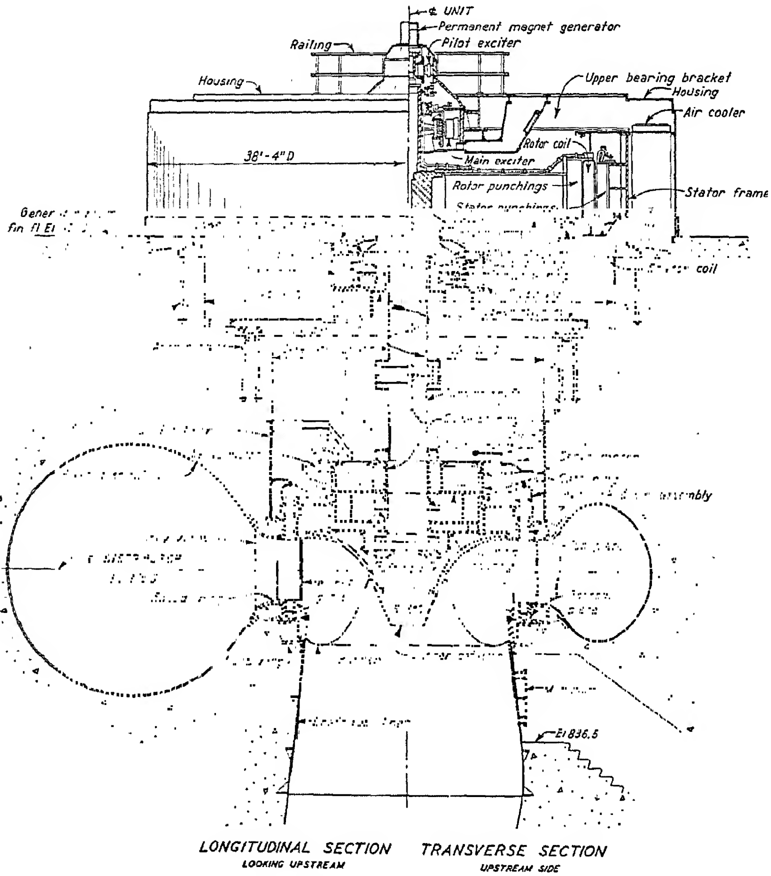


FIGURE 36.—*Turbine and generator arrangement.*

The stator frame is of welded rolled steel-plate construction and was built in four sections to facilitate shipment and erection. The stator core is built of silicon steel laminations clamped in place by bolts and butted together at the four joints. Ventilating fans on the rotor circulate cooling air through the end turns and through the air gap and vent ducts between laminations. The hot air discharges between pairs of the surface air coolers, flows circumferentially through coolers, and returns over the top of the stator and through the bottom of the stator wrapper plate for recirculation. The ventilating system is sealed off at the bottom of the lower bearing bracket, thus providing a convenient working platform with ample headroom for bearing inspection. The exciters are separately ventilated.

Stator windings consist of stranded copper with mica tape turn and coil insulation, in accordance with AIEE standards for class B insulation. The stator was completely wound at the factory, except for the parting coils between stator sections; these were installed after the stator was assembled and alined in the powerhouse. The main and neutral leads are brought out between two of the surface coolers at the upstream side of the unit, where connection is made to the station cables. The 3-phase stator windings are star-connected with two equal circuit groups connected in parallel to form each phase. The neutral is grounded through a breaker and a 1-ohm reactor. To keep the windings dry while the unit is idle, ten 2-kilowatt heaters are distributed inside the generator air enclosure below the stator windings.

Twelve resistance temperature detector coils, embedded in the armature windings to obtain winding temperatures, connect to indicating and recording instruments located on the control room recording board.

The rotor spider arms are of fabricated steel plate and the rim is of laminated steel. The rotor is designed for a maximum runaway speed of 190 revolutions per minute. The field poles are built up of punched steel laminations and are held in dovetailed slots in the rotor rim by keys and wedges. The poles can be removed without removing the rotor from the stator. Field windings consist of edge-wound copper strips with asbestos turn and sheet mica pole body insulation, conforming to AIEE class B standards. The generator brake shoes bear on a brake ring, with removable wearing surfaces, which is mounted under the rotor. Six combination brakes and jacks are mounted on the thrust bearing bracket main beams and side arms. Compressed air is used for braking and oil for jacking. The air pressure is controlled manually at the actuator, and the oil pressure is applied by a portable oil pump to be connected to the air header when required.

Amortisseur windings consist of low-resistance bars inserted in slots in each pole piece and silver-soldered to segments at each end. They are nonconnected between poles and are designed so that the ratio of quadrature to direct axis subtransient reactance will not exceed 1.3.

Collector rings placed above the rotor are fitted with suitable brush rigging and direct connections to the main exciter armature. A pilot brush on each of the two rings, together with a field shunt, is used for indicating and recording temperatures in the field winding at the recording board in the main control room.

The forged steel generator shaft, 33 inches in diameter, is machined and polished. A 6-inch-diameter bore hole was drilled for inspection of the forging. The shaft is a single forging with an integral flange at the bottom to connect with the turbine shaft, two at the top to support the rotor, and a heavy intermediate flange to carry the rotating load to the thrust bearing.

The upper bracket, which supports the stationary exciter parts and the top air enclosure plates, consists of fabricated steel beams supported on pads on top of the stator frame. The lower bracket, which supports the combined thrust and guide bearing, consists of two main beams spanning the turbine pit and resting on four sole plates. A side arm is framed to each side of the main bracket to insure stability.

The thrust bearing, which is located below the rotor, is the Kingsbury type with flat shoes, and is designed to carry a maximum load of 450 tons. The shoes are supported by adjustable jackscrews arranged so that each shoe may be adjusted independently. The bearing is immersed in oil, which is cooled by water coolers placed in the oil reservoir. Bearing parts are so designed that sections may be taken out horizontally through openings in the oil housing. The openings are normally sealed with gasketed covers. The guide bearing is of the adjustable-shoe type and is located in the same oil reservoir with the thrust bearing.

The exciter field rheostat and circuit breaker are located in the electrical bay at elevation 900. The regulator main control element, cross-current compensator, and voltage-adjusting rheostat are all mounted on the main control switchboard. The main control element is the noncontinuous vibrating type responsive to average 3-phase voltage and designed for high-speed excitation. The regulator is capable of responding to alternating-current voltage change within a period of 3 cycles and is sensitive to a 0.5 percent voltage variation.

Fire protection nozzles are located in ring headers above and below the rotor. The nozzles are connected to the carbon-dioxide fire-extinguisher system No. 1. The control is operated automatically by thermostats placed in generator hot-air ducts, or by the generator differential relays, and manually by switches on the actuator cabinet.

A rotor erection pedestal in the service bay at elevation 900 supports and alines the rotor arms during assembly and stacking of the rotor. This pedestal will also be used to support the rotor when a unit is dismantled. No special provisions were made for bearing bracket assembly, since it is possible to support the bracket on wood cribbing placed on the service-bay deck at a height sufficient to permit assembly of the shaft and bearing parts.

Exciters

A separately excited 220-kilowatt main exciter and a compound-wound self-excited pilot exciter are connected to the main shaft of each generator above the generator housing. The exciters have class A insulation. Air for the exciters is drawn from the generator room, passed downward through the exciters, and discharged into the generator room through a discharge duct designed to prevent recirculation of heated air.

Main low-voltage switch gear

Connections from the generator terminals to the main low-voltage switch gear housings are made with compact-sector-type, varnished cambric-insulated, shielded, rubber-jacketed cables, carried in separate fiber ducts embedded in the generator room floor. Two 1,750,000-circular-mil cables per phase are used. The ends of each cable have built-up creepage terminals, and the shielding is grounded at one end.

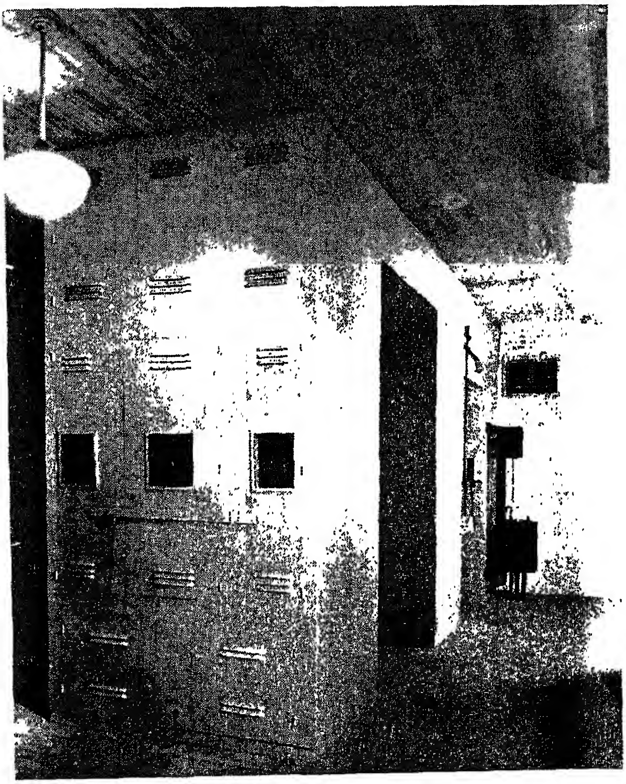


FIGURE 37.—*Main low-voltage switch gear housing.*

The switch gear housings (see fig. 37), which are sheet steel with asbestos-cement barriers, and the neutral reactor cubicles are located in separate rooms, thereby affording complete isolation of this equipment. The connections continue through the housings as bare copper bar conductors on porcelain insulators to facilitate the connections to instrument transformers, disconnect switches, breakers, and surge protective equipment located in the housings. The breakers are rated 15 kilovolts, 2,000 amperes, 1,000,000 kilovolt-amperes interrupting capacity. The housings of units 1 and 3 also enclose switch gear for the station service transformers.

Each generator neutral reactor with its oil circuit breaker and disconnect switch is enclosed in a steel cubicle in the electrical bay. The reactor design was based on maximum current flow of 4,000 amperes for 1 minute, with all heat stored within the reactor, and a temperature rise of 195° centigrade above an ambient temperature of 40° centigrade. It is insulated for 15,000 volts, the reactance is 1 ohm, and the resistance is 0.1 ohm.

Connections from the switch gears to the main transformers in the switchyard are made with compact-sector-type, paper-insulated, shielded, lead-covered, lead-protected cables carried in fiber ducts encased in concrete envelopes. Two 1,750,000-circular-mil cables are used per phase. Paper-insulated lead-covered cable was selected as most economical for these longer runs. The shielding tapes and lead sheaths are grounded at one end of each length, and the resulting sheath voltage is less than 18 volts. Acceptance of the sheath voltage was considered better than acceptance of circulating currents, which would increase the temperature of the cables, thereby requiring larger cables. The configuration of the cables in each duct bank was designed to minimize unbalanced currents between parallel cables of a phase.

Main control switchboards

The controls, instruments, and relays for the major electrical equipment of the powerhouse and switchyard are centralized at a seven-panel control benchboard and a seven-panel vertical back-to-back instrument and relay board in the control room. A five-panel board at the right end of the room controls and distributes power from the 250-volt station control battery, the 48-volt annunciator battery, and the 115-volt alternating-current preferred service. A six-panel board is placed at the left end of the room for recording instruments and load-frequency control equipment. All switchboards are totally enclosed cubicles of ⅛-inch stretcher-leveled steel with dull black finish.

All indicating and recording instruments are semiflush type, with dull black cases and white dials and charts. All equipment on the relay board is projection type, since some of the items on this board were not readily available in satisfactory semiflush cases. Appearance is of less consideration, however, on these relay panels, because they face the wall. Metal mimic busses of distinctive finishes to represent different voltages and control switches with handles of distinctive shapes and colors for various functions are arranged on the benchboard to agree with the physical arrangement of the controlled circuits.

The automatic load-frequency-control equipment consists of a unit-load controller for each generator, a station-load recorder, a tie-line load-recorded controller, a master load-frequency controller, and the associated selector switches and auxiliary devices required to accomplish any of the following operating conditions within the limits of the station's generating capacity: (1) Assist in system-frequency regulation, (2) maintain a predetermined load on a selected tie line, (3) maintain a constant output or station base load, (4) absorb local load changes, (5) maintain a predetermined load on each generator, (6) permit synchronous condenser operation of one or more units with automatic load pick-up in case of tie-line failure.

The main control storage battery floats at 258 volts across the output of either of two 20-kilowatt, diverter-pole-type motor-generator

charging sets. This dependable direct-current supply is used for oil circuit-breaker operation, miscellaneous control, emergency lighting, and operation of a small direct-current to alternating-current motor-generator set for an emergency supply to the 115-volt alternating-current preferred service bus. The battery has a capacity of 199 ampere-hours at the 1-hour rate, which is sufficient to carry the direct-current loads for 1 hour. An additional reserve capacity of 150 amperes for 1 minute is available for oil circuit-breaker operation. Battery distribution circuits are controlled by double-pole air-circuit breakers equipped with both thermal and instantaneous trip and with an interrupting capacity of 10,000 amperes.

The 115-volt alternating-current preferred service bus is used for station clocks, chart drive motors of recording instruments, and carrier-current telephone equipment. This bus is normally energized by a circuit from the lighting switchboard. Starting and stopping of the emergency supply motor-generator set and transfer of load are automatic upon failure and restoration of the normal supply circuit.

A six-element automatic oscillograph on the relay board records transmission line faults and checks the performance of protective relays. Current and potential circuits are connected to the oscillograph through a plug and block arrangement mounted back of the panel to facilitate the selection of any line.

To secure short excitation circuits, the pilot exciter rheostat, main exciter rheostat, main exciter field breaker, and voltage regulator contactors for each generator are assembled in a steel excitation cubicle located in the electrical bay opposite the generator. The voltage regulators are mounted on the respective generator panels of the instrument board in the control room, where they are under the operator's observation. The overvoltage relays for both the pilot exciter and the generator operate contactors which insert resistance in the pilot exciter and main exciter field circuits. This keeps the voltage within safe limits during periods of system disturbances or overspeed.

Controls for the unit auxiliaries and local manual controls for the turbine and governor equipment are mounted on combined gage and control boards which form the fronts of actuator cubicles on the generator room floor. Other station auxiliaries are controlled from local push-button stations near the equipment.

Control wiring between switchboards and controlled equipment consists of multiconductor cables which are insulated for 600-volt service with 35-percent performance rubber. Some are covered with 60-percent tough rubber jackets; others are covered with a tape and weatherproof braid; and the remainder are insulated with rubber compound and covered with tape and weatherproof braid. The change in the insulation and covering was due to wartime restrictions on the use of crude or reclaimed rubber during the fabrication of this cable. From the terminal blocks back of the switchboard panels, the cables are taken through floor slots to the spreading room below the control room, being carried on formed asbestos-cement trays through the powerhouse control cable tunnel or through 3-inch fiber duct runs to manholes in the switchyard and then routed through steel conduits to terminals at the equipment. The terminal blocks located back of the switchboard panels eliminate terminal cabinets on the floor below,

and the open-tray system of routing cables facilitates installation, inspection, and maintenance.

Relays

The generators are protected against faults by phase differential relays of the induction type, operating on percentage current differential, and by differentially connected ground overcurrent relays of the high-speed induction type. In addition, the generators are protected by back-up phase overcurrent relays of the induction type. Each generator is protected against overvoltage by an alternating-current overvoltage relay of the instantaneous type, operated in conjunction with a rectifier unit to make the performance of the relay independent of frequency.

Main power transformers and station service transformers are protected by phase differential relays of the induction type operating on percentage current differential. The main 154-kilovolt bus is protected by differentially connected overcurrent relays of the high-speed induction type.

The 154-kilovolt transmission lines are protected by 3-zone distance relays and high-speed current-polarized directional ground relays operated in conjunction with carrier-current pilot relays and auxiliaries. In addition, back-up ground relays of both the current-polarized and potential-polarized types are used on each line. Automatic single-shot recloser relays supervised by voltage check and synchronism check relays can be applied to each line by operation of appropriate selector switches.

AUXILIARY POWER

Auxiliary power at 440 volts is normally supplied from the main generators or from the 154-kilovolt system through duplicate 3-phase, 1,000-kilovolt-ampere station service transformers connected to the 13.8-kilovolt generator leads of units 1 and 3. Each station service transformer has sufficient capacity to carry the auxiliary power, heating, and lighting loads of the ultimate four-unit station. The demand of this load is estimated at 900 kilovolt-amperes. The connected load is 2,700 kilovolt-amperes.

Emergency power is supplied from a local 12-kilovolt rural line through a 3-phase, 600-kilovolt-ampere transformer. In the rare event of loss of all generation and transmission line connections, power to operate essential auxiliaries such as spillway gates, pumps, and lighting is obtained from a 200-kilovolt-ampere, gasoline-engine-driven generator set. This generator is controlled from a single-panel cubicle located in the gasoline engine generator room and can be connected to the air-conditioning board for periodic loading and testing.

Power from the two normal and two emergency sources is distributed to the unit auxiliary power boards, the common auxiliary power board, the air-conditioning board, the station lighting transformers, the unwatering pumps, the powerhouse crane, and the intake and spillway sections of the dam through air circuit breakers on a two-section main auxiliary power board located in the electrical bay between the transformers.

Duplicate bus sections on the main board, duplicate feeders to all important load centers, and duplicate and alternate equipment for the essential auxiliaries insure continuous operation of the auxiliary

services and also permit the retirement of parts of the auxiliary power system for inspection and maintenance without seriously curtailing plant operations. Main feeders are equipped with breakers at their source and double-throw selector switches at their destination to prevent the paralleling of the two normal auxiliary power sources.

The self-cooled 1,000-kilovolt-ampere transformers are filled with noninflammable liquid and located indoors. The switchboards are dead front, totally enclosed, and of steel cubicle construction with dull-black exterior finish and light-gray interiors. The two main incoming breakers and the bus tie breaker of the main auxiliary power board have an interrupting rating of 40,000 amperes, and the other breakers are rated at 20,000 amperes. The incoming breakers and bus section breakers are electrically controlled from the main control room. All feeder breakers on this board are manually operated. Circuits that connect direct to loads are controlled by fused knife switches and contactors with thermal overload elements. Individual motors and heaters are controlled at points of utilization.

Power circuits leaving the board consist of single-conductor cables, insulated for 1,000-volt service, with 35 percent performance rubber. Some are covered with a 60-percent tough rubber jacket, and some are covered with a tape and weatherproof braid. The change in covering was due to wartime restrictions on the use of crude or reclaimed rubber during the fabrication of this cable.

STATION SERVICE FACILITIES

Lighting and heating

The powerhouse alternating-current lighting system and small heaters are supplied from two 100-kilovolt-ampere, single-phase, noninflammable liquid-filled, 480–240/120-volt, indoor-type transformers. The primaries are connected to different bus sections of the main 440-volt auxiliary power switchboard. Each main lighting transformer and its primary feeder have a capacity of about 75 percent of the combined lighting and heating load. They are normally operated independently on the two halves of the system, but manual switching on the lighting and heating distribution board permits feeding the entire system from either transformer. The main lighting and heating distribution switchboard and transformers are centrally located in a room in the electrical bay. Low-voltage receptacle outlets in the turbine pit areas are energized from local transformers rated at 2 kilovolt-amperes, 230–115/32 volts.

Lighting for the switchyard, elevator tower, intake gate and sluice gate galleries, north and south embankment, and parking areas is supplied from local transformers fed at 440-volt current.

Distribution is by the usual mains, distribution cabinets, and branch circuits. Practically all switching is local at the point of utilization. All outside lighting is controlled by automatic photoelectric devices in addition to manual control.

The control room has a specially designed asymmetrical indirect lighting system utilizing an arched ceiling and a bank of cove lights along the side of the room behind the operator. Illumination of public areas within the control building will be provided by fixtures of special design selected to harmonize with the architectural features

when these areas are completed. Lighting in the generator room consists of high-bay direct-type overhead units. Other areas in the powerhouse are lighted with standard types of industrial fixtures. Substation-type fixtures are used for general lighting in the switchyard and along the yard fence.

Emergency lighting is supplied from the 250-volt station control battery. Emergency lights are located at all vital locations, such as the main control room, auxiliary power board room, switch gear rooms, stairways, and generator room, and are so spaced as to form a part of the normal lighting system. The lamps, which are of the 230-volt class, normally operate on the 230-volt alternating-current normal lighting circuits, but during a power failure an automatic throw-over switch connects them to the 258-volt station control battery. Upon the return of power, the switch automatically reconnects them to their normal alternating current.

An extensive system of protective floodlighting illuminates all approaches to the powerhouse, switchyard, and parking areas. The protective floodlighting is of a temporary nature and can be dismantled after the war without affecting the normal lighting.

Grounding system

The power and protective grounding system includes three low-resistance ground mats: one in the fill downstream from the powerhouse along the training wall, another in the reservoir near the north nonoverflow dam, and a third in the reservoir extending along the entire intake and spillway sections of the dam. The three grounding mats are connected to the station grounding network through test boxes in such manner that each mat can be tested separately. Tests using a remote reference ground indicate that the combined grounding mats have a resistance to earth of approximately 1.0 ohm.

Generator neutrals, transformer neutrals, lightning arresters, equipment frames, steel structures, and transmission towers are all connected to the grounding system. A protective ground network just below the surface of the switchyard equalizes potential gradients in the switchyard. Steel gratings are placed at operating points and grounded to the network to give additional protection to the operators. The general layout for grounding is shown in figure 38.

Signals and annunciator system

Audible and visual annunciation signals operate for excessive temperatures of bearings, windings, air and oil, abnormal liquid levels and flows, and faulty operation of equipment throughout the station. Those deserving the attention of the control room operator are located in the main control room, and those requiring the attention of the turbine room operator are located on the governer actuator boards.

In addition to the annunciator, an operation recorder, which automatically records all annunciations and all normal operations of major switching equipment, is mounted on the operator's desk in the control room. Each recording on the strip chart of the recorder identifies the source of the signal and records the date and time when the signal is printed.

Communication system

The local telephone system consists primarily of two units: a manual key-type switchboard of 12 lines built into the control room

operator's desk, used to terminate important direct circuits for use of the operator; an automatic switchboard of 40 lines installed in the telephone room, used for intercommunication between the various local telephone instruments distributed about the powerhouse, dam, and switchyard. Use of the automatic equipment avoids the necessity of disturbing the control room operator when local calls are made. The manual and automatic switchboards are interconnected by two 2-way dial trunks any one 1-way executive right-of-way trunk. The latter is used to allow the operator to make an urgent call to a busy line. The equipment permits conference service between six selected telephones. Fire and police signaling and code-call service for locating officials and employees are available by dialing appropriate numbers from any telephone instrument.

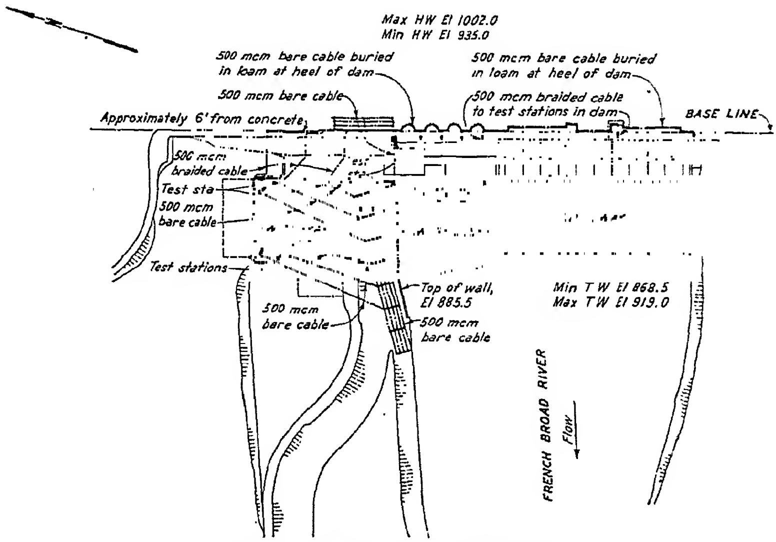


FIGURE 38.—*Electrical grounding system.*

Outside telephone service to other plants on the system is available by use of a single-frequency duplex carrier-current telephone channel operating over two-phase wires of the 154-kilovolt transmission lines. An extension telephone line from the local carrier-current apparatus is terminated on the operator's manual switchboard, and all communications to the load dispatcher and other generating stations on this carrier channel may be initiated by dialing the appropriate number of the remote station.

Emergency communication with the stations at opposite ends of the 154-kilovolt lines is also available by use of a portable test telephone attachment used to modulate the carrier pilot relay channel operating over each line section.

Leased wire lines of the Bell system are also available for use in reaching points not covered by the power line carrier-current system and as a stand-by for the latter.

Fire protection system

Two separate automatic carbon-dioxide fire-extinguishing systems are provided. System 1 protects the generators, and system 2 protects the oil storage, the oil purification, and the gas-electric generator rooms. Both systems are arranged for remote automatic electrical operation and for local manual operation.

System 1 consists of three banks of 50-pound cylinders, an initial discharge and a reserve bank, each consisting of 20 cylinders, and a delayed discharge bank of 14 cylinders. The initial bank is arranged for the simultaneous discharge of 20 cylinders to either generator. The delayed discharge bank is arranged for intermittent discharges to maintain sufficient concentration of carbon dioxide. In the 14,000 cubic feet of air space of one generator, an initial concentration of 55 percent of carbon dioxide is obtained, and a minimum concentration of 25 percent for 30 minutes is maintained. The reserve bank is arranged with interconnecting piping and controls to allow it to function in the same manner as the initial bank. The reserve cylinders can also be used as spares for system 2.

System 2 consists of one bank of 18 cylinders. Nine cylinders can be discharged into the 6,700-cubic-foot oil purification room, nine into the 6,700-cubic-foot gas-electric generator room, or the entire bank into the 19,000-cubic-foot oil storage room.

Portable carbon-dioxide fire-extinguishing units are conveniently located in the powerhouse and in the switchyard. One 100-pound wheeled-type unit is placed in the switchyard.

A supply of treated water, with fire hydrants and hose connections at convenient locations, is available for general fire protection in the powerhouse and in the switchyard.

Heating system

Since continuous occupancy is not expected except in certain areas, provision for heating to the conventional 72° Fahrenheit was made only in the air-conditioned spaces, the area around the turbine operator's desk, the public toilets, and a few other small areas. In other parts of the building, partial heat is supplied for the prevention of dampness and excessive chill.

Heating of the control room, the offices, and related spaces is integral with the air-conditioning system. In the lower floors of the electrical bay, the losses from the electrical equipment are sufficient for all ordinary heating. In other parts of the powerhouse, heat is supplied by local electric heating units of the gravity or forced convection type, as the service or location requires.

The outside temperature assumed for design purposes is 0° Fahrenheit. No attempt was made, except in the air-conditioned spaces, to offset heat losses as usually computed. In comparison with ordinary building construction, the walls are so thick and the mass of the structure so great that the lag in heat transmission and the thermal storage of the building are exceptionally large; therefore the conventional computation of heat losses would be practically meaningless. Instead, heaters were installed where maintenance or repair operations might be expected.

The total connected heating load in the powerhouse is 402 kilowatts. In addition to the permanently installed heaters, outlets for 4.5-kilo-

watt, 220-volt, single-phase portable heaters and for 18-kilowatt, 440-volt, 3-phase, fan-type portable heaters were located at strategic points.

Where practicable, heaters were designed for 3-phase operation at 440 volts to reduce loads on the lighting system transformers and for economy in wiring. The recessed convection heaters are for 220-volt single-phase operation. With a few exceptions, heaters are thermostatically controlled.

Ventilating system

In the design of the ventilating system, consideration was given to the usage of the various spaces, to their probable occupancy, to dampness, to heat generated by electrical equipment, and to heat from solar radiation transmitted through walls, roofs, and decks. In spaces having considerable occupancy by the employees or by visitors, air is changed frequently to prevent dampness or discomfort. Other spaces, such as electrical equipment rooms and areas under decks and roofs, have sufficient ventilation for the dissipation of excess heat without particular regard to comfort. The lower galleries and tunnels are ventilated to avoid stagnant and excessively damp conditions.

The design of the powerhouse is such that most of the more important spaces adjoin the generator room. The general method of ventilation is to exhaust the air from the generator room through the spaces to be ventilated and to discharge it outdoors. Air to replace that exhausted is supplied by two fans located in the fan room at elevation 914. In addition to the air required to replace that which is exhausted, a surplus is supplied by these fans for the dissipation of heat from the generators and from solar radiation on the deck.

The machine shop, battery room, electrical equipment spaces, oil purification and storage rooms, shops, and secondary spaces are ventilated by a number of small exhaust fans. These spaces are grouped together in several exhaust systems determined by location and similarity of ventilating requirements.

The quantity of air required for ventilation was arbitrarily determined except where removal of heat is concerned. For ventilation of attic spaces and rooms containing heat-generating equipment, a temperature rise varying (depending upon location, service, and occupancy) from 8° to 12° Fahrenheit was assumed, and air in sufficient quantities to maintain these temperature differentials was supplied. The quantity of air to be exhausted from other spaces was generally selected from recommendations of the American Society of Heating and Ventilating Engineers and from comparison with other installations of a similar nature.

The air mechanically exhausted is approximately 85,500 cubic feet per minute, of which 12,000 cubic feet per minute is exhausted through the attic space. The quantity of air introduced by fans into the generator room is 96,500 cubic feet per minute. The excess of air supplied above that exhausted escapes to the outside through openings in the generator hatch covers.

The fans for moving air are conventional-type electric-motor-driven centrifugal blowers, except the turbine pit supply fans which are of the axial flow type. The fans are either belt-driven or direct-connected to their driving motor, depending on their location and duty. Two-speed motors are used with a number of the fans for flexibility

of operation. Sheet metal ducts are fabricated from galvanized iron and are reinforced with standing seams or structural steel angles. Inlets and outlets to ducts and openings through walls are fitted with grilles or wire guards according to location and importance of appearance.

Air-conditioning system

The air-conditioning system serves the control room, the offices, the telephone and first-aid rooms, and related spaces. The system may be used for cooling, heating, or ventilating as required. Because of the variation in heating requirements, the air-conditioning space is divided into three zones, each of which may be heated, cooled, or ventilated independently.

The control room at elevation 928.33 comprises one zone, the offices at elevation 928.33 comprise a second zone, and the first-aid and telephone rooms at elevation 914 comprise a third zone. The offices were grouped together because of similar exposure and similar thermal loads. The control room was treated separately because the heavy internal heat load from electrical equipment and the lack of outside exposure will require cooling during periods when the other spaces may require ventilation or heating. The first-aid and telephone rooms were treated separately because of their remote location with respect to either of the other systems.

The design of the heating equipment and the arrangement of its controlling devices are such that during the heating cycle a temperature of 72° Fahrenheit may be maintained. The capacity of the equipment is based on an assumed outside temperature of 0° Fahrenheit. The computed sensible heat load is approximately 365,000 British thermal units per hour. To increase the flexibility of the heating system that serves the offices and to permit individual control of the rooms, only part of the required heat in the office zone is supplied by the blast heater; the balance is supplied by recessed convection heaters in the individual rooms. All heat for the control room and the first-aid and telephone rooms, except the incidental heat of the internal electrical equipment, is supplied by zone blast heaters.

Humidification of the control room and office zone during the heating cycle is accomplished by the discharge, into the supply duct, of steam generated by electric immersion heaters in an open evaporating pan. Humidification for the first-aid and telephone rooms is supplied by discharging a spray of atomized water into the supply duct. The equipment is automatically controlled and is designed to maintain a relative humidity of 40 percent for average winter conditions.

The capacity of the cooling equipment is such that it will maintain an inside temperature of 78° Fahrenheit, with an accompanying relative humidity of 50 percent when the outside temperature is 95° Fahrenheit and the relative humidity is 48 percent.

During the cooling cycle, the air-conditioned spaces are cooled by the circulation of chilled air through the same fan and ducts used for the distribution of warmed air in the winter.

The fresh air is mixed with the recirculated air, filtered, and passed through cooling coils, where it is chilled and dehumidified, and then distributed to the conditioned spaces. The cooling coils are finned-surface type employing chilled water as a cooling medium. The degree

of cooling in the individual zones is regulated by the thermostatic control of the flow of chilled water through the coils.

Water for the coils is chilled by refrigerating machinery located in the service bay at elevation 900 and is pumped to the individual cooling coils as required. The refrigerating machinery consists of a Freon F–12 motor-driven compressor, a condenser, and a shell and tube water cooler, with control and accessory devices located in the lower elevation of the service bay. When its temperature is sufficiently low, water drawn from the reservoir may be bypassed around the refrigerating equipment and used in the cooling coils.

The computed heat load on the present cooling equipment is 368,000 British thermal units sensible and 81,000 latent; and for the future lobby the computed load is 168,000 British thermal units sensible and 62,000 latent; the total ultimate load is approximately 57 tons refrigeration. The capacity of the water-chilling equipment installed is sufficient for the ultimate load.

The three cycles of operation for each zone, namely, the heating cycle, the cooling cycle, and the ventilating cycle, are separately controlled. The control of each cycle is so interlocked with the control of the other cycles that only one cycle may be operated at a time. The selection of the cycle of operation is manual, and each zone may be operated on any cycle, independent of the operation of the other zones.

The arrangement of the controls for each zone is such that during the heating cycle only those parts of the system that are essential to the supplying and regulation of heat are operative. Likewise, during the cooling cycle, only those parts of the equipment and control which are essential to the cooling operation are active.

The control of the refrigerating machinery and the chilled water pump is interlocked with the control of the cooling cycle of the three zones in such manner that chilled water is supplied when demanded at any coil.

To conserve vital war materials, the interior finishing of the public lobby was deferred until some future date. Provisions and allowance, however, have been made for the future installation of heating, cooling, and ventilating equipment for the public lobby and its related spaces. The anticipated design for the public lobby is exactly similar to that of the control room.

Drainage system

All powerhouse, spillway, and intake drainage below normal tailwater elevation discharges directly into the station drainage and unwatering sump located in the basement of the service bay. Powerhouse drainage, including the septic tank effluent, above tailwater elevation normally discharges directly to the tailrace but may be bypassed to the sump during periods of high tailwater. Roof and deck drains discharge directly to the tailrace.

The capacity of the sump is 23,500 gallons. Normal drainage is pumped to the tailrace by two 300-gallon-per-minute, deep-well, turbine-type pumps, with vertical motors mounted on the basement floor of the service bay at elevation 884. The bottom of the sump is at elevation 832. Operation of the regular pumps is automatic, and the draft tube unwatering pump is available in case of emergency.

A drain and equalization line connects the spillway drainage gallery to the sump. Drainage is normally discharged to the sump. If an excessive amount of leakage accumulates in the gallery during high water conditions, it may be necessary to allow the gallery to fill to tailwater level. If this condition exists, the proper valves are operated to permit the excess leakage to equalize to the tailrace, preventing any pressure or uplift upon the spillway structure greater than that caused by tailwater. A second equalization line is provided from the spillway gallery at the left training wall, with valves set to equalize excess leakage to tailwater automatically. This method of equalizing accumulated leakage to the tailrace also guards against the possibility of exceeding the sump pumping capacity, which might flood portions of the powerhouse.

Unwatering system

It was necessary to provide means for unwatering the draft tubes and scroll cases to allow access to the turbine for purposes of inspection or repair within these areas. To accomplish this, a screened outlet 1 foot above the low point of the draft tube was connected to a 12-inch drain with control valve which leads to the station drainage and unwatering sump.

The drain valves for all scroll cases are operated from the powerhouse drainage gallery at elevation 856. The drain valves for units 2, 3, and future unit 4 draft tubes are located between units 2 and 3 and are operated from drainage gallery at elevation 856. The drain valve for unit 1 draft tube is operated from the service bay floor at elevation 884 directly above the sump. One 3,000-gallon-per-minute, deep-well, turbine-type pump is provided for use during unwatering periods. This pump has a vertical motor mounted over the sump at elevation 884; the pump is manually controlled and may also be used to augment the station drainage pumping capacity. A 3,000-gallon-per-minute, deep-well, turbine-type pump was purchased as a spare for use at this project or at the Cherokee project if necessary.

Future unit 4 can be connected into both of the above systems. Temporary connections were made to the deferred unit 2.

Water systems

Treated water.—All treated water for the powerhouse and switchyard is supplied from a spring located on the right bank of the river. A combined spring house and pumping station was built to prevent the water from becoming contaminated and to house two 75-gallon-per-minute pumps, a meter, reagent tanks, and three hypochlorinators, one for feeding a hypochlorite solution, one for feeding a solution of hexametaphosphate, and one serves as a spare for either. The minimum recorded flow from the spring is 85 gallons per minute.

The water is pumped to a 50,000-gallon steel storage tank and flows from the tank to the powerhouse through a main located in the switchyard. The main is connected to the fire hydrants in the switchyard and extends through the powerhouse to elevation 884 in the service bay. At this location the water branches into two systems. For one system the pressure is reduced to approximately 75 pounds per square inch and serves the sanitary fixtures and numerous 1-inch service outlets scattered throughout the powerhouse for floor flushing and fire protection. The other system remains at an unreduced pressure and

is carried through the spillway and intake drainage gallery and terminates at the end of the gallery on the left bank where is can be extended for any future developments of the left bank of the river.

Raw water.—Raw water is obtained from the penstocks through intake lines equipped with twin strainers which can be cleaned without interrupting operation. The water flows by gravity to the main generator air and oil coolers, emergency gasoline-engine generator cooling system, stationary air compressor cooling system, air-conditioning compressor, turbine bearing stuffing box, and turbine runner seals.

This system differs from the system installed at the Cherokee project only in the fact that no pressure-reducing valves are required since the headwater pressure is lower at this project.

Governor and lubricating oil system

All storage tanks and pumping and purification equipment are located on the elevation 884 floor of the service bay. The oil-storage facilities consist of one dirty and one clean oil tank of 3,660-gallon capacity each. The pumping equipment consists of one clean and one dirty oil pump, each of 30-gallon-per-minute capacity. The purifier capacity is 350 gallons per hour.

A complete piping system circulates the oil in the governor system, generator bearing, turbine bearing, and to and from the purification system. The use of three-way valves affords flexibility in the oil system and prevents the mixing of clean and dirty oil. The system was designed for extension to serve the future units.

Compressed-air system

A complete piping system, with service outlets, distributes compressed air about the powerhouse and to the generator brakes. A stationary, single-stage, [illegible] motor-driven air compressor is located on the elevation [illegible] of the service bay. The compressor capacity is 105 cubic feet per minute at a pressure of 100 pounds per square inch. The system includes a water-cooled aftercooler and a 197-cubic-foot-capacity air receiver, with automatic control of the air pressure.

Compressed air for the governor system is independent of the station air system and is supplied by an 8-cubic-foot-per-minute compressor, complete with piping system, operating at 300-pound-per-square-inch pressure. This compressor was furnished by the turbine manufacturer.

Water in the draft tubes may be depressed below the turbine runner by manually admitting compressed air from the station air system into the draft tube through the turbine head cover.

A portable, air-cooled, motor-driven, air compressor of 105-cubic-foot-per-minute capacity at 100-pound-per-square-inch pressure has also been included for general service around the entire project, wherever required.

Automatic elevator

A passenger elevator, with a rated live load of 5,000 pounds at a car speed of 250 feet per minute, was installed in the dam. The total lift of approximately 81 feet is from the bottom landing at elevation 928.33, which gives access to the powerhouse lobby through a gallery, to the top landing at elevation 1009. There is one intermediate land-

ing at the intake gate hoist gallery at elevation 999. Operation is controlled by automatic push buttons of the single-call type. All hoisting machinery and control panels are installed in the machinery room at elevation 1024.17.

The car platform, with an inside area of approximately 48 square feet, is made of hardwood supported by heavy steel frame and braced with rods to the cage. The cage is structural steel, bolted and riveted together. The car enclosure is built of polished furniture steel and is complete with kick plates, handrail, rubber tile flooring, indirect lighting, emergency exit, and telephone. Doors open automatically when the car stops at a landing.

The hoisting machine is of the standard gearless traction type. The guides for both car and counterweight are planed-steel T-sections. The brakes are electromagnetic-released, spring-set, with two shoes independently operated. Auxiliary equipment includes compensating chains, guide lubricator, counterweights, and oil buffers.

The electrical system consists of a motor-generator set, hoist motor, automatic push-button control, automatic leveling devices, automatic door operators, terminal and final limit switches, car lighting, signal lights, and telephone. The motor-generator set is rated 440/250 volts, 45 horsepower, and is fitted with a speed regulator. The hoist motor is a direct-connected, reversible, gearless, open-frame type.

Powerhouse gantry crane

The powerhouse gantry crane is used in normal operation of the power station to handle turbine and generator parts, transformers, and other miscellaneous equipment for maintenance or repair. It also serves, by means of a jib crane on a downstream leg of the crane, for operation and servicing of the draft tube gates, bulkheads, and slot fillers. The crane travel covers the full length of the powerhouse, service bay, and the erection space north of the service bay.

The main hoists have sufficient capacity to handle the turbine assembly or the generator rotor as individual units. The lifting speed of the main hoists is low to ensure safe handling of the larger pieces of equipment; this also permits the auxiliary and main hoist motors to be interchangeable and minimizes power requirements. Since approximately 90 percent of the lifts required will be made with the auxiliary hoists, a higher lifting speed was desirable. The moderate trolley and bridge speeds used are in conformance with standard practice for this type of service.

The lifting beam from the Norris project is to be used for attaching the load to the two main hoist hooks when making heavy lifts up to the full capacity of the crane.

The crane consists of two trolleys running on a track supported on a traveling gantry structure (see figs. 39 and 40). The trolleys and other equipment mounted on the gantry are housed in the top of the structure for protection from the weather. Each trolley is equipped with separate controls and has one main hoist of 112.5-ton capacity, one auxiliary hoist of 25-ton capacity, and a traversing mechanism. The gantry is supported on 16 wheels, 8 at each end, mounted in 2-wheel equalizing trucks. An integrally mounted indvidual motor drive, connected to the two wheels of one equalizer truck at each corner of the gantry structure, propels the crane; 8 wheels are driven in this manner.

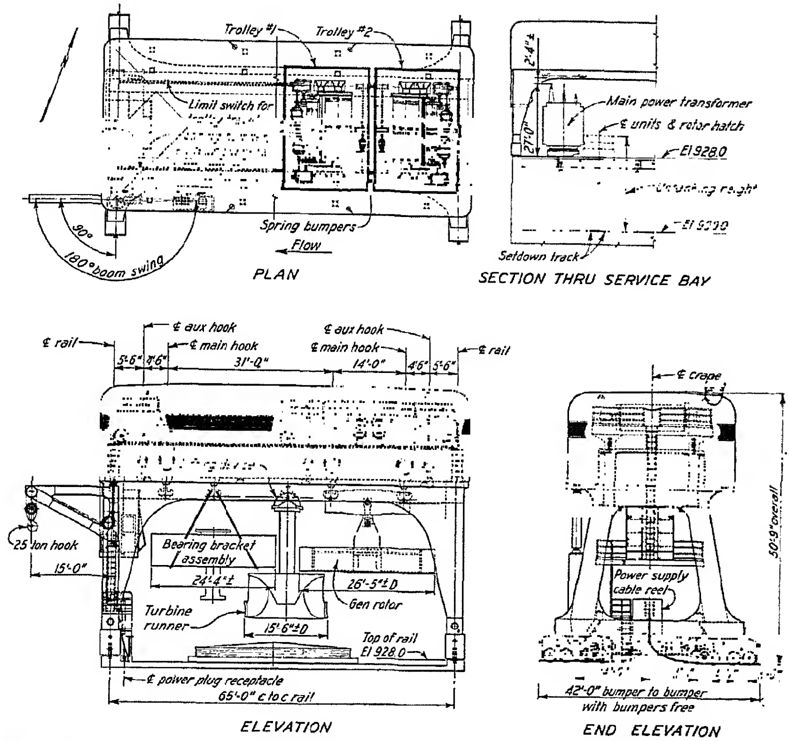


FIGURE 39.—*Powerhouse 225-ton-capacity gantry crane—Plan, elevations, and section.*

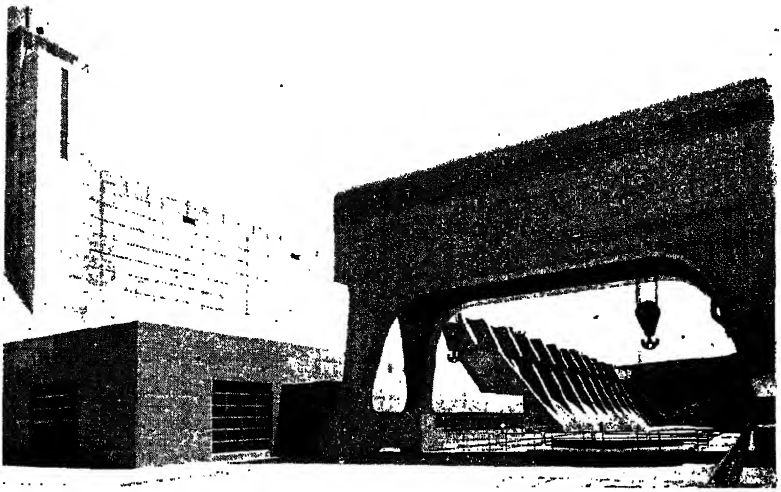


FIGURE 40.—*Control building and powerhouse gantry crane.*

The crane is controlled from an operator's cab, mounted at the west end of the crane between the gantry legs and just below the main girders. The jib crane for draft tube gate operation, mounted on one corner of the gantry structure, has a capacity of 25 tons. The capacity of the jib crane was determined by the lifting force required to break a gate loose when seated in the closed position.

Service bay crane

The service bay crane is installed under the generator deck and serves the turbine and rotor erection areas. It handles the miscellaneous small parts of the turbines, rotors, transformers, and other equipment when they are being assembled or serviced in this area.

The crane bridge is a single I-beam and channel girder supported on fixed-end trucks of two wheels each. A trolley-type suspended hoist is mounted on the lower flange of the girder. Bridge and trolley travel are manually controlled from the floor by hand chains. The hoist is electrically driven with a 6.5-horsepower motor, controlled from the floor.

Machine shop equipment

All equipment for the machine shop was purchased in accordance with TVA standard specifications. All machines have individual electric motors with starting controls mounted on the machine or in a convenient location near the machine. The shop equipment includes two lathes, two grinders, two drills, one shaper, one power hacksaw, one pipe-threading machine, and some small tools.

SWITCHYARD

The switchyard is located on the north bank of the river, immediately downstream from the dam and adjacent to the powerhouse, where the natural terrain and necessary grading were favorable for TVA's low-type switchyard construction. The heavy electrical connections from the generators to the transformers are relatively short, and the transformers stand directly behind the switchyard bays into which they are connected (see fig. 41). The finished switchyard grade is at the same elevation as the powerhouse deck and access road which greatly facilitates the handling of equipment. When untanking of the main transformers is required, they can be rolled onto the transfer car and lowered into the service bay by the powerhouse crane.

The ultimate 154-kilovolt switchyard layout provides for two main transformer banks to serve four generating units (see fig. 42). Units 1 and 2 are to be connected to transformer bank No. 1 and units 3 and 4 to transformer bank No. 2. The initial construction included two generating units, one main transformer bank, and two 154-kilovolt transmission lines to Cherokee and Alcoa. In 1944 a 110-kilovolt switching structure was added to the existing structures.

General design and arrangement

The general layout and cross sections of the switchyard are shown in figure 42. Generation is at 13,800 volts. Two generators are connected through a single bank of transformers to the 154-kilovolt bus, and synchronizing is done by low-voltage breakers. This arrangement, by requiring one high-voltage switching bay for each pair of generators, resulted in greater economy than was secured in some of

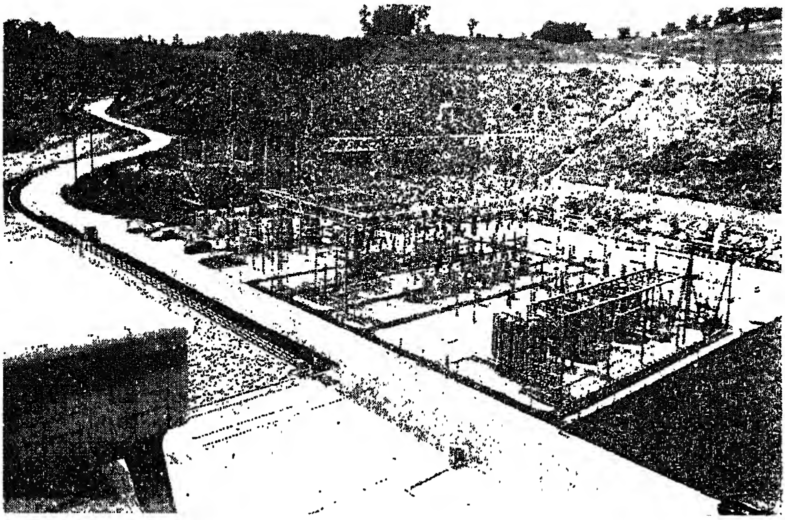


FIGURE 41.—*Switchyard.*

the earlier TVA plants where each generator was connected through its own transformer bank to the 154-kilovolt bus. Although some flexibility is lost, the present size of the power system is so great that the additional flexibility of individual transformer banks is not so important as it was in the earlier stages of the power system development.

In the initial installation, the two station service transformers are connected to the low-voltage side of the one main transformer bank through motor-operated disconnect switches and, for the present, are switched and relayed with the main transformer bank. When the second main transformer bank is installed, each station service transformer will then be served from a separate source.

The 154-kilovolt switchyard is designed for a future main-and-transfer-bus arrangement, with two main transformer banks and four transmission lines. Each main transformer bank will be connected to both buses through an oil circuit breaker and to the transfer bus through a motor-operated disconnect switch. This arrangement will provide two spare breakers for the entire yard. The motor-operated bus sectionalizing switches permit sectionalizing the buses for split operation of the transmission system.

The switching structure and equipment are so arranged that during the early stages of development of the station, when not more than four circuits are required, a ring bus with one breaker per circuit can be used. When desired, the ring bus can readily be developed into the main and transfer bus with one breaker and one disconnect per circuit by extending the same structures and adding breakers and disconnects as needed. If extreme flexibility should be required, the yard can be converted into the conventional double-bus double-breaker system with two breakers per circuit by adding a breaker and a disconnect to each line circuit without structural changes.

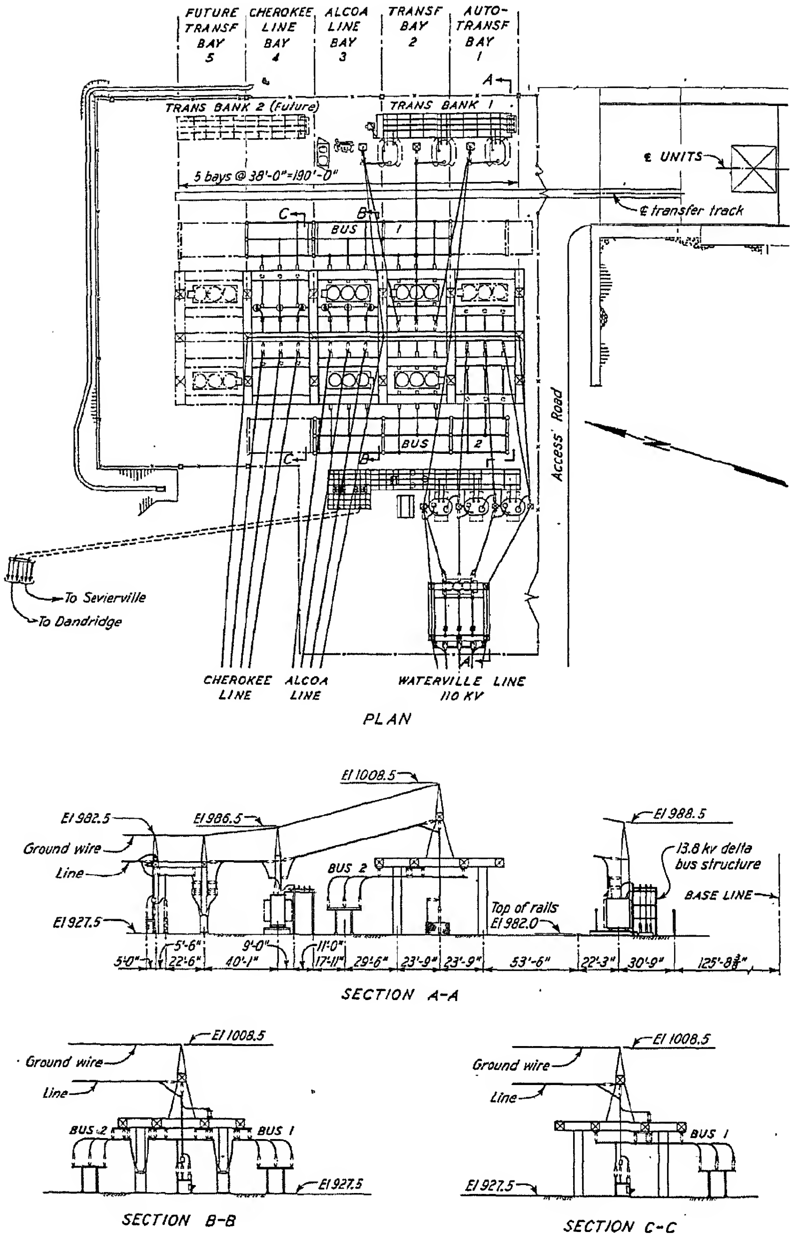


Figure 42.—*General plan and sections of switchyard.*

Main transformers and reactors

Main step-up transformer bank No. 1, which is connected to two generators, consists of three 20,000/26,667-kilovolt-ampere transformers. They are so proportioned to the combined generator rating as to operate without blowers at generator loads somewhat below the 60° generator rating and with blowers at greater loads.

Since two generators are connected to a transformer bank, single-phase transformers were selected because a 3-phase unit of the required capacity would have been too large for existing transportation and handling facilities. Other projects in the TVA system have spare single-phase transformers of approximately the same rating and characteristics which can be used if needed and therefore a spare transformer was not included at this station.

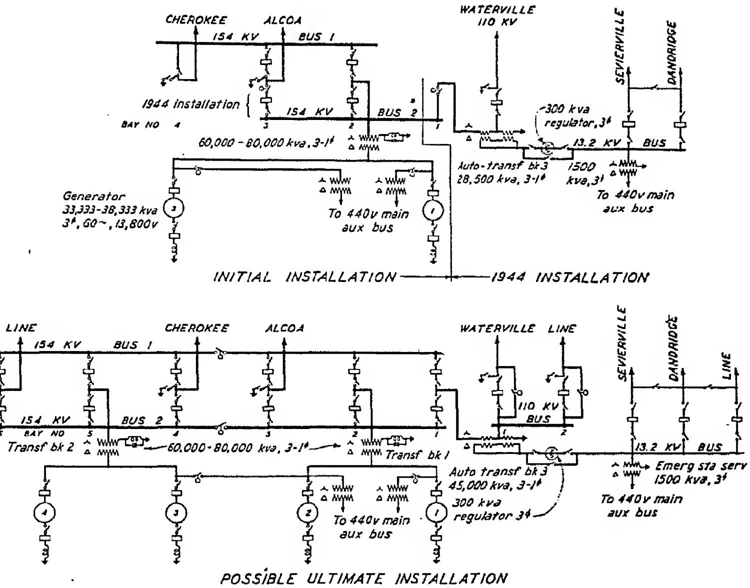


FIGURE 43.—*Electrical development diagrams.*

Each transformer is equipped with manual no-load tap-changing equipment on the high-voltage windings, inert gas equipment, magnetic oil gage, oil temperature thermometer with alarm contacts, and resistance-type winding temperature detector for operation of a temperature recorder located in the main control room. The 13.2-kilovolt low-voltage terminals of the transformers are connected to buses which are supported on a structure to form the delta connection. High-voltage windings are connected Y with the neutral grounded through a 51.3-ohm neutral grounding reactor to limit fault current.

Switch gear

The breaker is an 8-cycle opening, nonreclosing, standard-duty type and is rated 161 kilovolts, 1,200 amperes, 2,500,000 kilovolt-

amperes interrupting capacity. Disconnect switches are 3-pole gang-operated. The isolating switches are manually operated while the line switch is motor-operated from the main control board. The line disconnect switch is provided with grounding blades for grounding the transmission line.

Buses and insulators

The 154-kilovolt buses are designed for a span of 38 feet and a maximum deflection of less than the outside diameter of the conductor. The conductor consists of 4½-inch-diameter standard galvanized steel pipe for buses and similar 3-inch pipe for taps. Joints are welded, and the welds are zinc-sprayed outside and asphaltum-painted inside. The conductors are supported on 4-inch, pedestal-type porcelain insulators. Flexible connections at terminals of equipment prevent excessive stresses on the porcelain. Connections from breakers to disconnects and from the outgoing disconnects to the line take-offs are of stranded copper cables supported on strain insulators.

Carrier-current and miscellaneous equipment

The switchyard carrier-current equipment includes the transmitter-receiver unit for generating and receiving the carrier-current signals used for pilot relaying, the coupling capacitors for coupling the carrier-current signals to the power line, the line traps for confining the carrier-current signals to appropriate line sections, and the line-tuning unit which connects the carrier-current telephone transmitter-receiver to the line-coupling capacitors.

The line traps, coupling capacitors, line-tuning unit, and relaying transmitter-receiver unit are mounted on a steel structure in the center of the line bay. This structure also acts as a lower support for the vertical connection to the line. The relaying transmitter-receiver cabinet and the carrier telephone line-tuning cabinet are located so that they can be serviced from the ground. Phase B is used for carrier-current relaying, and phases A and C are used for carrier-current telephone communication.

Each line-coupling capacitor is equipped with a potential device. The secondary windings of these devices supply three-phase potential for line relaying, indicating instruments, and synchronizing.

Insulation coordination and lightning protection

Electrical insulation and protective devices were carefully selected and coordinated to insure a safe margin of insulation strength above the maximum abnormal voltages permitted by the protective equipment during faults, switching surges, and lightning surges.

The overhead ground conductor from the transmission line is carried across the top of the switchyard to form a network supported by and grounded to steel peaks rising from the top of the steel structure. The network is sufficiently extensive to include all equipment and conductors within a protective cone whose base is equal to its height. The multiple points of support for the overhead network are thoroughly grounded to the grounding system below the switchyard, and the grounding system is connected by underground cables to the footings of the nearest transmission-line tower. The general grounding system is shown in figure 38.

Transformer neutrals are grounded through a relatively low reactance shunted by arresters to reduce as much as possible the abnormal voltages resulting from system faults. Grounded neutral-type arresters are placed at the transformer high-voltage terminals. Each arrester has a reseal voltage high enough to prevent flow of 60-cycle power following an arrester discharge; and the equipment insulation is chosen with a safe margin above the maximum breakdown voltage of the arrester, taking into account the circuit distance between the location of the insulation and the nearest arrester. Spill gaps are provided on each transmission line in the switchyard.

Generator surge protective arresters are as close as possible to the terminals of each generator to discharge the abnormal voltages, while the electrostatic capacity of the single-conductor generator leads serves to slope the fronts of incoming surges.

Autotransformer bank

The purchase of the transmission systems of the Tennessee Public Service Co. and the Tennessee Electric Power Co. in east Tennessee and the expansion of the TVA's transmission system in the same area made it possible to coordinate the acquired facilities with those of the TVA with considerable simplification. The changes included the connecting of the Waterville line into the TVA system at Douglas Dam instead of Arlington substation.

The 110-kilovolt Waterville line was connected to the 154-kilovolt Douglas [illegible] through a bank of three single-phase 161/112.7–14.17-kilovolt, [illegible], water-cooled autotransformers. The 154-kilovolt switching was extended into a 4-circuit, 4-bay, ring-bus arrangement. The 14.17-kilovolt tertiary winding of the transformer bank was connected through a 300-kilovolt-ampere step-type voltage regulator to a new 13.2-kilovolt bus with 3-shot reclosing breakers to feed the Sevierville and Dandridge areas. A 13,200/480-volt transformer was installed to replace the previous emergency station service transformer and to ground the 13.2-kilovolt system.

All major equipment used in this installation, except the voltage regulator and the grounding transformer, was made available by changes in other parts of the TVA system. The transformer bank, the 110-kilovolt switching, and the 13.2-kilovolt switching were located immediately west (downstream) of the 154-kilovolt switchyard. Space is available for one additional 110-kilovolt line and one additional 13.2-kilovolt line and in the 154-kilovolt yard for the second transformer bank (for generators 3 and 4) and for one additional 154-kilovolt line.

Steel structures

The switchyard structures are similar in design to those used at the Cherokee project. The framed bents for the 154-kilovolt switching structure consist of two columns 47 feet 6 inches center to center, with cantilever supports for the disconnect switches, and a center tower for the outgoing lines and transformer connections. The bents are spaced 38 feet on centers and consist of 5-foot-square latticed box members. The main and transfer buses are supported on separate bents in the yard. The transformer structure consists of three independent towers of 5-foot-square latticed construction, with a ladder

and platform inside each tower to give access to floodlights mounted near the top of the tower.

In the 110-kilovolt yard the switching structure is a 4-column rectangular structure, 28 by 31 feet in plan, with provision for a 31-foot bay extension. Columns and girders are 3-foot-square laced angle box members except the girder supporting the vertical switches, which is 3 by 5 feet in cross section. Three independent towers of 3-foot-square latticed box members support the transformer switches and connections. The delta bus and the 12-kilovolt yard structure are of conventional design, consisting of wide-flanged beams and columns.

The outgoing transmission lines from the 154-kilovolt structure were strung to produce a maximum tension of 4,000 pounds per phase wire and 3,000 pounds per ground wire at 0° Fahrenheit when loaded with ½-inch radial coating of ice under an 8-pound wind. They were designed for a maximum pull-off angle of 15 degrees horizontally in the line. Line tensions for the 110-kilovolt phase and ground wires were assumed as 2,000 and 1,500 pounds, respectively.

All steel is hot-dipped galvanized, and all field connections are bolted. Shop welding was utilized to simplify details and to reduce the number of bolted connections.

Concrete structures

The original riverbank rose steeply in the switchyard area and required considerable excavation to secure a level area. The underlying rock was uncovered just north of the location for the second transformer bank. This resulted in the foundations for the structures in the initial yard being placed on overburden or earth fill of varying depth.

Since differential settlements between column lines were undesirable for the tower structures, pile supports were carried to rock under all main tower foundations. Foundations for future bays will be on rock. The general excavation for the future additions was done with the original work so that when extensions are required the necessary foundations and structures can be erected without interrupting the operation of the plant. For transformers, oil circuit breakers, and minor structures, spread foundations were used. They were designed with low soil pressures.

All cables are carried in concrete ducts poured in place on the ground. Manholes were placed as required for pulling cables and draining the duct lines.

Transformer transfer car

The transformer transfer car consists of a heavy structural steel frame mounted on four wheels that travel on the rails of a standard-gage track in the switchyard. Rails are mounted transversely across this frame to match the rails on the transformer foundation and to support the transformer during transportation. At one side of the car these rails and their supporting brackets extend to a point approximately 1 inch from the ends of the rails on top of the transformer foundation. When transformers are to be pulled on or off the car, this gap is spanned by special splice bars bolted to the two sets of rails. The car is prevented from tipping, and the ends of the car rails are supported by steel wedges driven between the supporting brackets and shelf on the transformer foundation. A manually operated single-

drum winch for pulling the transformers on and off is mounted at one side of the car. The maximum design load for the car is 90 tons, and the wheels and the journals are designed for a maximum static wheel load of 50,000 pounds each. The winch is designed for a pulling force of 4,000 pounds.

Insulating oil system

All storage tanks, pumps, and purification equipment are located on the elevation 884 floor of the service bay in the powerhouse. The oil-storage facilities include: two dirty-oil tanks, each of 5,030-gallon capacity for transformer oil; one dirty-oil tank of 6,420-gallon capacity for circuit breaker oil; and one clean-oil tank of 6,420-gallon capacity for transformer and circuit breaker oil. The pumping equipment consists of one 100-gallon-per-minute clean-oil pump. No dirty-oil pump was required since all dirty oil drains by gravity from the switchyard equipment to the storage tanks. The purifier with filter press has a capacity of 600 gallons per hour.

A complete piping system conducts the oil in the switchyard equipment to and from the purification system. A supply and return line is used to carry oil to and from the transformer repair bay located on the elevation 900 floor of the service bay. Flexibility in the oil-handling system is obtained and the mixing of the clean and dirty oil is prevented by the use of a three-way valve on the purifier suction.

All connections between the switchyard equipment and the piping system are made with flexible hose through 2-inch drain lines and 1½-inch fill lines. The system was designed so that it could be extended to serve future switchyard squipment.

Fire protection

A portable-type carbon-dioxide fire-extinguishing unit and a supply of treated water give fire protection in the switchyard. Three 4-inch fire hydrants with 2½-inch outlets are located so that any part of the switchyard may be served with water by connecting two 50-foot lengths of 2½-inch hose to the proper hydrant. The hose is reeled on a portable fire-hose cart, and both the hose cart and the portable carbon-dioxide extinguishing equipment are stored in a fire-protection equipment building in the switchyard.

To prevent injury by electrical shock to the operator of the fire-fighting equipment, two atomizing nozzles are used which break up the jet of water into spray.

MISCELLANEOUS PUBLIC FACILITIES

Public visitors' facilities are to be completed within the powerhouse. These facilities were included in the original plans, but the work was deferred because of the war. Included are public toilets, visitors' reception space, and information displays.

On the north side of the French Broad River, a visitors' parking overlook was constructed to enable the visiting public to view the dam, the lake, and the Great Smoky Mountains. Another parking area for visitors was built immediately adjacent to the switchyard.

On the south side of the river provisions were made for the future development of a public recreational area which includes an overlook building, parking areas, a boat landing, and picnic facilities.

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Chapter 4

CONSTRUCTION PLANT

To achieve the goal of building Douglas Dam, including the installation of one hydroelectric power unit in the brief time of 13 months, required careful and skillful planning of the construction program and the fullest utilization of trained men, equipment, and construction plant items from other TVA projects. The layout and the design of the construction plant, the selection of equipment and methods, and the solution of numerous problems had to be accomplished in much shorter time than generally allowed a project as large as Douglas Dam.

Principal materials quantities to be handled by the plant were estimated to be 540,000 cubic yards of concrete; 530,000 cubic yards of rolled earth fill, and 490,000 cubic yards of earth and rock excavation. The construction schedule (fig. 44) called for first placement of concrete June 1, 1942.

Construction of plant facilities began immediately upon authorization of Douglas project by the TVA Board of Directors February 2, 1942. The construction schedule called for closure by March 1, 1943, and the first power unit on the line by May 1, 1943. Actually, closure was made February 19, 1943, and unit 3 was placed in commercial operation March 21.

The close similarity in the design and layout of Douglas Dam to that of Cherokee Dam made it possible to adopt many of the construction plant features developed for Cherokee. Also, since construction operations at Cherokee were near completion at the time of Douglas authorization, it was possible to transfer from Cherokee to Douglas not only most of the construction plant structures and equipment, both fixed and mobile, but also the highly experienced construction organization.

Normally the planning and procurement for construction plant installations (construction equipment, structures, and utilities) is handled in the central office. The bulk of immediate and urgent work required by the emergency schedule resulted in the delegating to the field office force the working out of plans for river diversion, cofferdams, raw and fresh water systems, sewers, and compressed-air distribution. The central office force, besides preparing the construction schedule, were to work out the construction plant layout; select fixed and mobile plant equipment, and arrange for its purchase or transfer; and prepare specifications and cost estimates. They were to study the best methods of producing, storing, and conveying aggregates and sand; of transporting and handling cement; of mixing concrete and placing it in the dam; to design and detail all structures in connection with these activities; and make layouts for necessary roads and railroads in the construction area. The construction plant should be such

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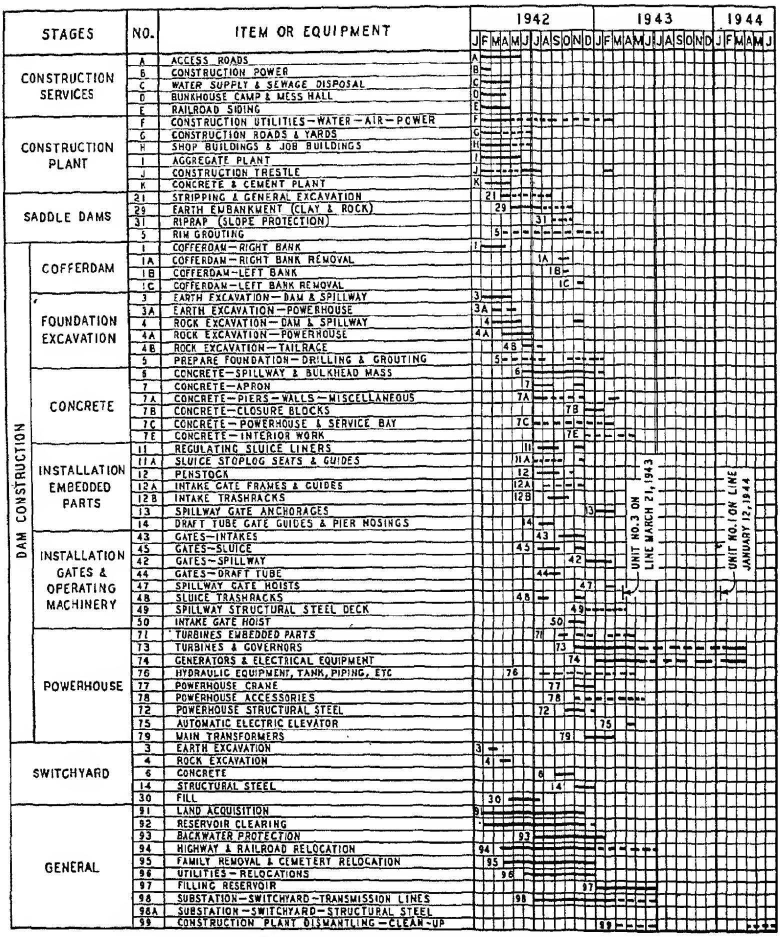


FIGURE 44.—*Construction schedule.*

that it would assure that the results desired could be attained in an economical and practical way and within the limited time allowed for building the dam.

Preliminary studies and layouts of the construction plant were started in October 1941. There were many major problems to be solved and several important decisions to be made before actual construction could begin. These studies are discussed under "Preliminary Studies on Construction Plant," page 123.

The decision to contract for aggregates was reached at an early date. Investigations and exploratory drilling at the dam had proven the existence of two quarry sites, close together, on the right bank of the river and beginning at a point about 2,300 feet from the base line of

the dam. The rock in these quarries was dolomite of the Knox formation and suitable for concrete aggregates. There were, however, within the TVA no available crushers, screens, or other equipment necessary for the processing of aggregates and sand, nor any personnel to operate a crushing and sizing plant. New equipment was difficult to obtain, and delivery dates were uncertain. These obstacles led to the decision that the best procedure the TVA could follow if it were to avoid postponing the date set for concreting to start would be to have a reputable contractor operate the quarries, produce the aggregates and sand, and store the material in a stock pile, from which the construction forces could reclaim it. This contract was awarded the Birmingham Slag Co. of Birmingham, Ala., February 2, 1942, only 3 days after Congress had authorized the TVA to proceed with the construction of Douglas Dam. This contractor had just completed his contract to deliver concrete aggregates and sand to Cherokee Dam and was in a position to transfer his equipment immediately. However, the contractor needed some additional equipment, on most of which he had an option.

The principal units of the construction plant in the final layout were all located on the right bank of the river downstream from the dam (see fig. 45). The aggregate processing plant consisted of two quarries, the crushing and sizing plant with one primary crusher, four secondary crushers, one rod mill, screens, and five stackers for storing aggregates and sand (see fig. 46). This part of the construction plant was installed and operated by the contractor. Figure 47 shows the flow diagram for the contractor's aggregate plant. The stock pile contained four sizes of aggregates and one size of sand with total storage capacity of 50,000 tons. The stock pile was protected against high water by a dike with the top at elevation 890 and was located over a timber reclaiming tunnel. By a system of five belt conveyors, material was carried to the mixing plant which was located at the north end of the construction bridge (see fig. 48).

Cement was transported by rail direct to the cement-storage silo next to the mixing plant and was unloaded from the cars with power shovels into a hopper feeding two flight conveyors. These conveyors transported the cement to two bucket elevators which in turn delivered the cement to either the mixing plant or the cement silo. Cement stored in the silo was reclaimed by a chute feeding the bucket elevators.

In the mixing plant the aggregates and the cement were stored in bins at the top. From these bins the aggregates and the cement flowed by gravity into batching hoppers, from which the material was discharged into a conical hopper which could feed any one of the three 4-cubic-yard mixers. From the mixers the concrete was dumped into a wet-batch hopper. This hopper was conical in shape with a gate at the bottom. Below this hopper a track was installed so that trains carrying concrete buckets could be brought in and loaded. These trains transported the concrete out on the triple-track construction bridge to revolving cranes, which picked up the buckets from the flatcars and placed the concrete in the form. The plant was designed to produce 264 cubic yards of concrete per hour, based upon a 4.4-cubic-yard batch. The maximum placed in 1 month was 104,000 cubic yards.

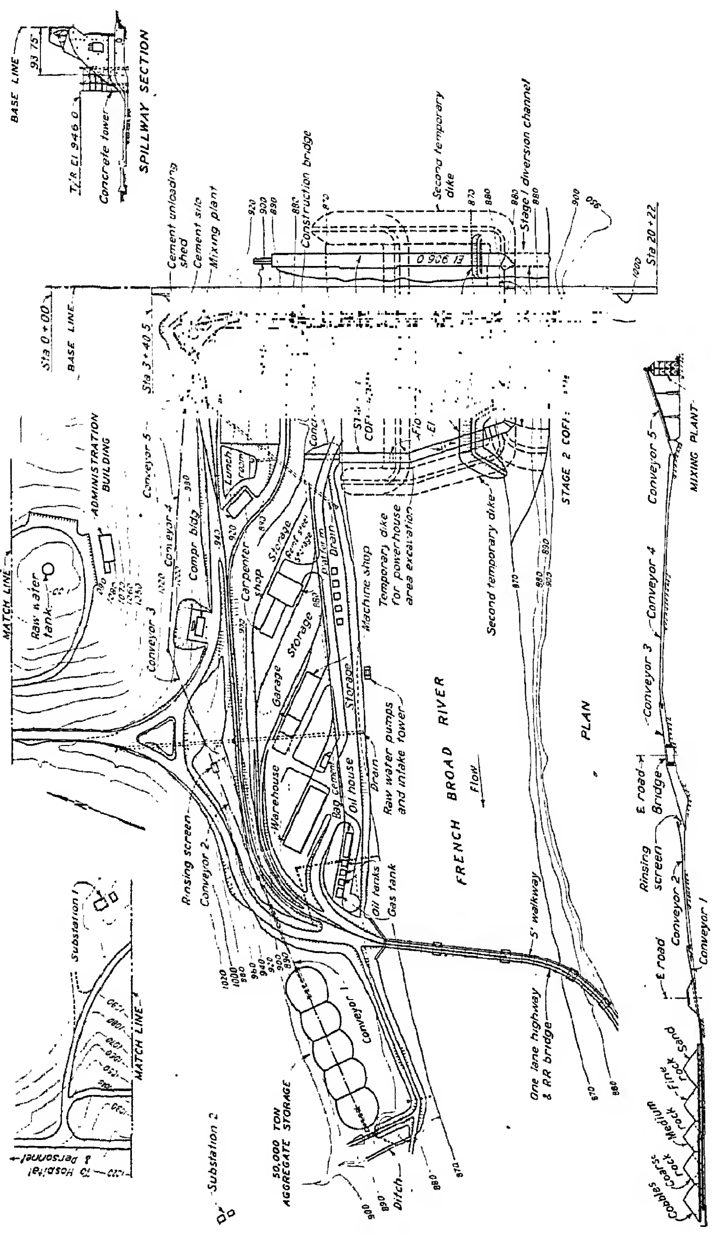
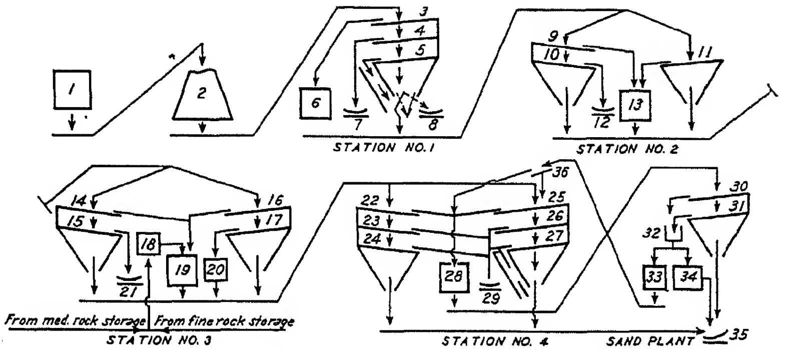


FIGURE 45.—Plan of construction plant.

FIGURE 46.—*Aggregate plant.*



SYMBOLS:

1..42" gyratory crusher
2..Surge pile
3..6" mesh screen (3 sect.)
4..3" mesh screen (3 sect.)
5..$2\frac{1}{2}$" screen (or less)
6..$5\frac{1}{2}$" cone crusher
7..Cobbles stacker belt
8..Rejected materials belt
9..3" mesh screen (3 sect.)
10..$1\frac{7}{8}$" screen (2 sect.); 2" (1 sect.)
11..1" mesh screen (3 sect.)
12..Coarse rock stacker belt
13..$4\frac{1}{4}$" cone crusher
14..$1\frac{3}{4}$" mesh screen (3 sect.)
15..$\frac{7}{8}$" screen (2 sect.); 1" (1 sect.)
16..$\frac{3}{4}$" mesh screen (3 sect.)
17..$\frac{3}{8}$" mesh screen (3 sect.)
18..Collecting bin
19..4" cone crusher
20..Impact crusher
21..Medium rock stacker belt
22..$\frac{7}{8}$" screen (2 sect.); $\frac{1}{2}$" (1 sect.)
23..$\frac{3}{8}$" mesh screen (3 sect.)
24..$\frac{5}{32}$" mesh screen (3 sect.)
25..$\frac{7}{8}$" screen (2 sect.); $\frac{1}{2}$" (1 sect.)
26..$\frac{3}{8}$" mesh screen (3 sect.)
27..$\frac{5}{32}$" screen (2 sect.); $\frac{3}{8}$" (1 sect.)
28..Hammer mill
29..Fine rock stacker belt
30..2-$\frac{1}{4}$" and 1-$\frac{3}{8}$" } Two units-identical
31..3-$\frac{5}{32}$" sect.
32..Collecting hopper
33..Type R crusher
34..Rod mill
35..Sand stacker belt
36..$\frac{1}{4}$" mesh screen

FIGURE 47.—*Flow sheet, contractors aggregate plant.*

Access roads were built on both sides of the river, and from an existing railroad a branch line was installed to the dam site. The road and the track crossed the river on an access bridge built downstream from the dam.

When the project was authorized, the general plans of the construction plant and the electrical distribution system had been ready for some time; the design of the combined railroad and highway access bridge was well advanced; drawings showing the general arrangement of the aggregate belt conveyors and the concrete placing construction bridge had been completed; specifications had been prepared and bids requested for new structural steel towers and deck framing for the construction bridge, the conveyor equipment, and the tunnel gates, as well as for concrete aggregates, so that awards could be made as soon as possible after authorization.

Work at the dam site was started January 29, 1942. The placing of concrete began May 31, 1942; on February 14, 1943, less than 13 months after the start of construction, the final closure of the only remaining gap was made, and 5 days later the filling of the reservoir began. On March 21, 1943, the first unit was in commercial use.

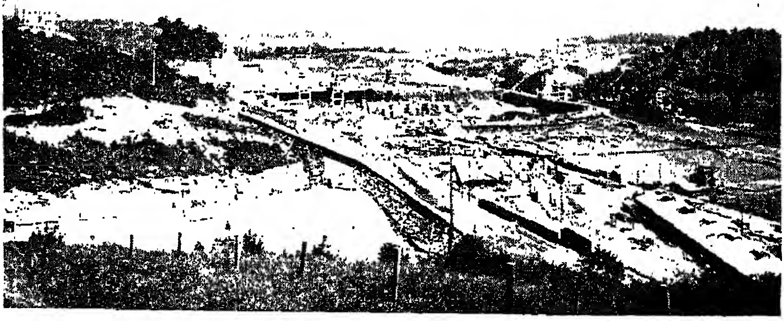


FIGURE 48.—*Construction plant.*

To obtain these results in such a short period, an uninterrupted work schedule had been necessary. Except for Christmas day, 1942, the work went on day and night, 7 days a week. In spite of delays in deliveries of material and equipment due to wartime conditions, shortage of manpower, unusually heavy rainfall and high river flows, and last but not least the difficult cofferdam unwatering problems, the project was completed in record time. This construction record was achieved by good management and excellent cooperation throughout, of course, but it could also be attributed in no small measure to the plant and equipment which had been selected.

PRELIMINARY STUDIES

Topography in the construction plant area

At the dam site, the French Broad River flows in a west-southwesterly direction. On the right bank, or the north side of the river, a 300- to 400-foot-wide flood plain extends from the dam site downstream past the quarry sites. The elevation of this plain varies between 875 and 890 feet. From this level area the terrain rises to elevations between 1,000 and 1,100 feet. On the left bank, or the south side of the river, a flood plain of varying width exists. At the dam site the width is about 250 feet but a steep bluff gradually narrows this down until 1,300 feet further downstream the flood plain ceases to exist. Several hundred feet further downstream the bluff recedes and another flood plain begins. At the dam site the bluff rises abruptly from the flood plain, average elevation of 880 feet to an elevation of 1,000 feet or more.

Access roads and railroad

Preliminary investigations indicated that access to the dam site could easily be obtained by constructing short access roads connecting to existing county roads on both sides of the river. Access by rail also appeared possible. The Smoky Mountain Railroad runs a line between Knoxville, Tenn., and Sevierville. This line passes through Ewing, Tenn., on the west side of the Little Pigeon River. Ewing is only 5 miles from the dam site, and the topography between these points is such that a branch line could be built without difficulty and at a reasonable cost. This line would permit bringing in the greater part of the construction materials and permanent equipment via railroad and greatly simplify the transportation problems. The Smoky Mountain Railroad Co., some years before the construction of Douglas Dam was authorized, had petitioned the Interstate Commerce Commission for permission to abandon their line. This action was postponed in anticipation of the authorization of Douglas Dam and the great advantages of railroad service to the project.

Because the railroad would come in on the south side of the river, it would be necessary to build an access bridge across the river. A combined one-lane highway and railroad bridge could be designed and built from structural steel available from the aggregate trestle at Cherokee Dam. The bridge would be capable of carrying a 73-ton steam locomotive hauling 85-ton freight cars. A 2-cubic-yard shovel (with counterweights, dipper, and dipper stick removed) weighing 80,000 pounds could safely be taken across. The bridge also would include a 5-foot-wide walkway for pedestrians.

Concreting plant

Because the quarry sites were situated on the right bank, it was logical to locate the aggregate and the concrete mixing plant on this side of the river. The stock pile could be located on the flood plain just upstream from the quarry. At high water the reclaiming tunnel under this stock pile would be flooded, but it could be protected by building a dike around the stock pile.

At Cherokee Dam most of the construction plant was or would be available for transfer to other TVA projects. Because Douglas Dam was very similar to Cherokee Dam, it was only logical to plan on

transferring to Douglas the usable items of plant structures, equipment, and buildings. The concrete mixing plant, the cement silo, the two bucket elevators, and the two flight conveyors used for handling cement could be arranged almost in the same manner as at Cherokee Dam. This would permit using the same drawings as were issued for Cherokee.

The method of placing concrete with revolving cranes running on a steel construction bridge had proven to be very successful at Cherokee Dam. Part of this bridge, two of the revolving cranes, and most of the trains for hauling concrete from the mixing plant to the cranes were still available for transfer. The concrete structures at Douglas Dam extended for about the same length as at Cherokee Dam, and the sequence of nonoverflow sections, spillway section, and powerhouse was similar. It was therefore decided to transfer the aforementioned equipment and part of the bridge from Cherokee Dam and use it at Douglas Dam. Plans contemplated locating the construction bridge so that the center line of the bridge would be 71 feet 6 inches from the center line of generating units and so that the top of crane rail would be 18 feet above the powerhouse deck.

Studies were required to determine how much new steel would be required to supplement the construction bridge towers and spans which could be transferred from Cherokee Dam. Before studies for Douglas Dam began, part of the original construction bridge had already been earmarked for Apalachia Dam and had been shipped to this project in the fall of 1941. While all deck spans had been salvaged at Cherokee Dam, only the upper part of the towers which extended beyond the concrete structure had been saved.

Eighteen deck spans were available for Douglas Dam, but 6 additional deck spans and 10 towers were needed to complete the construction bridge framing.

Purchasing new steel towers undoubtedly would have delayed erection of the construction bridge and necessitated postponing the start of concrete placing. The possibility of using reinforced concrete towers of the rigid-frame type was investigated and found to be feasible. Even though they would be more expensive than steel towers, the urgent need of completing Douglas Dam as scheduled justified the decision to use reinforced concrete towers. In the powerhouse, the part of the towers which extended above the mass concrete would have to be built of structural steel because of close clearances and to facilitate dismantling. The north tower in the powerhouse had to be purchased new; the other three steel towers in the powerhouse could be fabricated partly from tower steel which had been salvaged at Cherokee Dam; but some new steel was required. The two towers north of the powerhouse could be built entirely of reinforced concrete, so that no delay would be encountered in getting started with the bridge erection. The lower part of the six towers south of the powerhouse would have to be built of reinforced concrete, but there was available sufficient tower steel which, by adding a few pieces of new steel, could be used for the upper part of five towers. For the last tower at the south end of the bridge the steel structure would have to be purchased new. Besides new steel columns and bracing, new splices and column slabs were needed, and a majority of existing columns would have to be cut and milled for bearing.

It was possible to use deck spans transferred from Cherokee Dam for the first nine spans, beginning at the north end of the construction bridge (the mixing-plant side). This would provide 500 feet of bridge, including 123 feet of approach spans, from which concrete placing could be started. It was contemplated to request the successful contractor to fabricate and ship steel in such sequence that the erection of the bridge could start at the north end and proceed southward with a minimum of interruptions.

From the track to the cement unloading point a siding connected with the service track, which was the downstream track on the bridge. In preliminary studies it was contemplated to support this approach siding on a timber trestle across the switchyard and to use a 20° curvature. This location would later interfere with switchyard construction, and the siding was therefore changed to the location shown in figure 45. A 30° curve was necessary, but it not only eliminated interference with switchyard structures but also greatly reduced the length of the timber trestle.

In the preliminary layouts the mixing plant was located the same distance from the base line of the dam as the middle track, but subsequent studies showed that to avoid interference with the excavation at the north abutment it was necessary to move the mixing plant 24 feet farther downstream. For the same reason it was impossible to use a timber trestle or earth fill to support the tracks from the end of the construction bridge to the mixing plant. Therefore a two-span skew bridge approach supported on a concrete abutment and concrete piers was planned. Fortunately, sufficient structural steel to fabricate these spans was available within the TVA.

Shop area

Several studies were prepared to determine a suitable location and arrangement of the shop area. At the time these studies were started, it was assumed that the quarry site nearest the dam would also be used. The crushing and sizing plant as well as the stock pile would have to be located some distance upstream from the quarry. To obtain storage of 50,000 tons, as required in the specifications, meant that the stock pile would have to be 565 feet long. Preliminary investigations indicated that this did not leave sufficient space between the stock pile and the anticipated location of the switchyard to accommodate the various shop buildings, storage yards, and track facilities.

Topographic maps and inspection of the site indicated that about 2,000 feet downstream from the dam a fairly level area was situated on the south side of the river. The area was apparently large enough to accommodate the warehouse, the shop biuldings, and the storage yards; grading work would not be too expensive; and it would be above the highest known river level. Subsequent studies resulted in three different schemes. In all three schemes, rail and road facilities were adequate. From the access railroad on the south bank of the river a siding could be brought up to elevation 980, and cars could be switched in to the various shops and storage yards. The access road from the south would go through the shop area and descend on an 8-percent grade to the access bridge across the river to the right bank where the quarry, the aggregate, and concrete plants were to be located.

Another scheme in which shop biuldings, storage yards, and the administration building were located on the south side but closer to the dam and with railroad connection to the construction bridge was given up as impractical because it would mean excessive grading, would involve considerable rock excavation, and would necessitate the construction of an expensive approach trestle to the construction bridge. Combining access bridge and construction bridge into one structure would interfere with concrete-placing activities. This scheme was abandoned. The advantages of having the shop area on the south side of the river were that ample storage space would be available and the amount of earthwork involved would be small. There were, however, several disadvantages connected with this location, the principal ones being the long distance from the construction area and the difficulties of crossing the river by ferry until the access bridge had been completed. In these schemes considerable trackage was also required.

The possibility of locating the shop area on the flood plain on the north side of the river was studied in a fourth scheme. If the upstream quarry site was not used, this location would be feasible. The access bridge in this scheme (the adopted scheme; see fig. 45) was moved downstream to a location almost 2,700 feet from the base line of the dam. This made available a sufficiently large area between the river crossing to accommodate not only the stock pile, but also the warehouse; the machine shop; the carpenter shop; the lumber, oil, and gasoline storage; and miscellaneous small shops and job buildings. A parking area for cars was also provided. Thus, a shop area close to the construction area and the aggregate plant could be obtained. Another important advantage would be the delivery of materials from Cherokee without having to cross the river. Less trackage was required in the fourth scheme than in the other three schemes, and the shop area would be on the side of the river where construction would begin. The greatest draw-back to the scheme was the low elevation of the flood plain. To insure against the shop area being flooded, it would be necessary to elevate the ground by filling to elevation 892 for protection against a 15-year flood. In the final arrangement the access bridge was moved to a location 2,100 feet downstream of the dam, primarily as a safeguard against blasting at the quarry. This scheme was approved by the job management and was adopted as the final layout for the construction plant at Douglas Dam.

Cofferdams

Early in October 1941, preliminary cofferdam studies were made in order to estimate the number of timber logs required. A two-stage cofferdam was assumed, with the first-stage cofferdam extending from the right bank and enclosing the powerhouse and some of the spillway. The first estimate was based upon using 10-inch-diameter logs and building the cofferdam to a height which would give a safety factor, against being overtopped, of once every 1.9 years. For the first-stage cofferdam 29,000 logs would be required. These logs and the sheathing were expected to be obtainable in the reservoir area. A subsequent check revealed that it would be necessary to permit 8-inch minimum diameter logs in order to obtain sufficient timber for the cofferdam. By increasing the height of the cofferdam 5 feet, the danger of overtopping

would decrease to once every 3 years and the cofferdam would be safe for a flood of 60,000 cubic feet per second. About 49,000 logs would then be needed.

In the latter part of November 1941, an investigation was made of the possibility and advisability of constructing one large cofferdam to include the powerhouse and perhaps eight blocks of the spillway section in the first stage. River diversion would be provided by excavating a channel in the flood plain on the left bank. Such a channel along the steep rock bluff would permit blocking the existing river course by dikes in a similar manner to the scheme followed at Cherokee Dam and simplify construction of the cofferdam. The second-stage cofferdam would be short, extend from the left bank, and include the remainder of the dam. This scheme proved both feasible and economical. A 100-foot-wide channel with three 4-foot-diameter piers restricting the flow was assumed. Headwater curves were computed and they indicated that a cofferdam built to elevation 910 probably would be satisfactory.

Final design and details of the dikes and cofferdams were made by the field forces. The cofferdam construction is discussed in chapter 5.

SCHEDULES

Construction schedule

The construction schedule (see fig. 44) was based upon placing the first generating unit on the line within 14 to 16 months after authorization of the project. This agreed with the estimate prepared by TVA when it recommended the project to the War Production Board. The schedule called for the first unit to be in commercial use March 1, 1943, or 14 months after construction started. Concrete placing was scheduled to begin June 1, 1942. This would give the construction forces 4 months in which to get ready with plant, cofferdam, and materials; and well along with excavation and foundation preparation. This 4-month interval was based upon the time required for similar operations at Cherokee Dam.

A chronology of the more important dates of construction plant installation and operation is given in table 9.

Equipment schedules and costs

Figure 49 gives major construction plant equipment used at Douglas Dam and the number of equipment units on the job in any month. Table 10 gives costs of various classifications of plant and equipment. Table 11 gives costs of operating excavating and hauling equipment.

An itemized list and approximate cost of hauling, excavating, and hoisting equipment; drills; pneumatic tools; compressors; pumps; as well as equipment used for cement, concrete, and in the shops during the dam's construction is given in table 47 in appendix F. Some equipment was purchased new, but the majority of the equipment was transferred from Cherokee Dam and other TVA projects. A few items of equipment were rented.

TABLE 9.—*Construction plant erection, in-operation, and dismantling dates*

Item	Started	Completed
ACCESS HIGHWAYS AND RAILROADS		
Highways and roads:		
Repairing existing roads	Jan. 29, 1942	
Road to mixing plant area	do	
Temporary road to dam site, grading	Jan. 31, 1942	
Reinforcing highway bridges, south side of river	do	
Permanent access road, north side of river	Feb. 2, 1942	June 1942.
In service	February 1942	
Permanent access road, south side of river	Feb. 4, 1942	
In service	May 10, 1942	July 1942.
Roads connecting camp buildings:		
In service	February 1942	
Parking areas	Feb. 19, 1942	
Road to trailer camp	Mar. 16, 1942	
Saddle dam access roads	End July 1942	
[illegible] road to dam site):		
Bridge over Little Pigeon River	Feb. 9, 1942	April 1942.
Grading	Feb. 21, 1942	
Track laying	Mar. 18, 1942	
In service		May 10, 1942.
Yard tracks:		
Track E (access bridge to mixing plant)	May 1942	Early June 1942.
Track E (removal)	August 1943	September 1943.
Track No. 1	May 1942	
Tracks A, B, C, and D	June 1942	Early July 1942.
Highway and railroad access bridge:		
Drilling auger holes at north abutment	Jan. 31, 1942	
Barge construction	Feb. 10, 1942	
Excavation, north bank	Feb. 23, 1942	Feb. 25, 1942.
North abutment, timber crib	Feb. 26, 1942	Apr. 18, 1942.
Excavation, river	Feb. 27, 1942	
River piers, timber cribs	Mar. 29, 1942	Do.
Excavation, south bank	Apr. 4, 1942	
Steel erection	Apr. 18, 1942	May 1, 1942.
Steel and timber decking	Apr. 21, 1942	May 8, 1942.
Bridge placed in service		May 10, 1942.
Dismantling	Feb. 11, 1944	
SHOP AND YARD AREAS		
Clearing timber	Jan. 29, 1942	February 1942.
Grading	Feb. 1, 1942	End June 1942.
Drainage:		
Two 48-inch culverts under machine shop	Feb. 19, 1942	
Two 36-inch culverts under oil house	Feb. 20, 1942	End February 1942.
Fence around construction area	March 1942	March 1942.
JOB BUILDINGS		
Temporary offices, warehouse, and tool room	Jan. 30, 1942	February 1942.
Administration building:		
Excavation	do	Feb. 3, 1942.
Erection	Feb. 10, 1942	Mar. 22, 1942.
20- by 20-foot buildings	Feb. 5, 1942	
Explosives house	Feb. 9, 1942	
Warehouse	Feb. 14, 1942	End February 1942.
Garage, machine shop:		
Foundation for air hammer	do	
Building erection (except concrete floor)	Mar. 8, 1942	Mar. 27, 1942.
First-aid buildings	Feb. 14, 1942	
Field engineer's office	Feb. 19, 1942	
Time office	Feb. 22, 1942	
Carpenter shop and platform	Feb. 23, 1942	Mar. 26, 1942.
Warehouse sprinkler system	Apr. 21, 1942	Apr. 29, 1942.
Lubricant warehouse		End June 1942.
Fuel tanks:		
3 units	June 1942	Do.
2 units	do	
CAMP BUILDINGS		
Bunkhouses:		
Location staked out	Jan. 31, 1942	
Total of 2 units in service		Mar. 2, 1942.
Total of 3 units in service		Mar. 24, 1942.
Total of 4 units in service		Mar. 26, 1942.
Total of 5 units in service		Apr. 8, 1942.
Total of 6 units in service		May 11, 1942.
Total of 7 units in service		May 26, 1942.
Dismantling	August 1943	

TABLE 9.—*Construction plant erection, in-operation, and dismantling dates*—Con.

Item	Started	Completed
CAMP BUILDINGS—continued		
Cafeteria:		
Erection	Feb. 13, 1942	
In service		Mar. 2, 1942.
Additions		May 1942.
Store added		June 23, 1942.
Operation discontinued		July 21, 1943.
Women's dormitory:		
First unit	Feb. 21, 1942	Apr. 27, 1942.
Second unit		July 4, 1942.
Camp office and recreation building		April 1942.
Hospital and personnel building	Feb. 23, 1942	Apr. 13, 1942.
UTILITIES		
Treated water system:		
Temporary supply (from 15,000-gallon tank)	Early February 1942	March 1942.
50,000-gallon tank:		
Excavation	Feb. 3, 1942	Feb. 10, 1942.
Footings	Feb. 11, 1942	Feb. 22, 1942.
Steel erection	April 1942	April 1942.
Pumping station	Mar. 30, 1942	Do.
Permanent treated-water system completed		July 1942.
Raw water system:		
[illegible] lines laid	Jan. 29, 1942	
Excavation	Jan. 31, 1942	Feb. 3, 1942.
Footings	Feb. 7, 1942	Feb. 19, 1942.
Steel erection	Feb. 26, 1942	Mar. 28, 1942.
Raw-water intake:		
Timber crib and fill	Feb. 11, 1942	Feb. 23, 1942.
Pump installation	March 1942	March 1942.
Pumps moved to upstream face of dam	September 1942	September 1942.
Pumps moved to powerhouse	December 1942	December 1942.
Pipe lines:		
Excavation	Feb. 7, 1942	
Laying pipe	Feb. 20, 1942	Mar. 28, 1942.
Raw-water system:		
In service for air compressors	Mar. 17, 1942	
In service for whole job	Mar. 28, 1942	
Sanitary sewer system:		
Septic-tank construction	Feb. 28, 1942	Mar. 15, 1942.
Sewer lines:		
Excavation	Mar. 8, 1942	
Pipe laying	Mar. 20, 1942	
In service		Apr. 1, 1942.
Compressed air system:		
Temporary air lines	Jan. 29, 1942	
Excavation	Feb. 9, 1942	Feb. 25, 1942.
Compressor foundations	Feb. 25, 1942	Mar. 2, 1942.
Compressor-house erection	do	Mar. 26, 1942.
Initial compressor installation (2 units)	Mar. 6, 1942	Apr. 4, 1942.
First unit placed in service	Mar. 15, 1942	
Compressor-house extension	June 30, 1942	July 4, 1942.
Third compressor installed		July 1, 1942.
Construction power supply:		
Distribution lines for power and light	Feb. 2, 1942	
Electric light system, in service		Feb. 8, 1942.
Main substation, construction	Feb. 3, 1942	Feb. 9, 1942.
Main substation, in service		Feb. 15, 1942.
Aggregate plant substation, construction	Feb. 4, 1942	Feb. 9, 1942.
Aggregate plant substation, in service		Mar. 15, 1942.
Telephone service:		
In operation		Feb. 8, 1942.
COFFERDAMS		
First-stage cofferdam:		
Hauling and storing logs	Feb. 4, 1942	
Diversion-channel excavation	Feb. 14, 1942	May 5, 1942.
Excavation	Feb. 19, 1942	
Log-crib construction	Feb. 21, 1942	July 1942.
Temporary earth dike, downstream	Mar. 7, 1942	
Temporary earth dike, around powerhouse area	Mar. 13, 1942	Mar. 30, 1942.
Rock fill for cribs	Mar. 1, 1942	June 21, 1942.
Clay core	Mar. 11, 1942	July 1942.
Grouting to prevent leakage	Apr. 8, 1942	September 1942.
Cofferdam flooded	May 21, 1942	June 2, 1942.
Cofferdam entirely completed		July 1942.
Removal	October 1942	Early December 1942.

Table 9.—*Construction plant erection, in-operation, and dismantling dates*—Con.

Item	Started	Completed
COFFERDAMS—continued		
Second-stage cofferdam:		
River arm	Oct. 16, 1942	November 1942.
Diversion	Dec. 13, 1942	
Unwatering		Dec. 17, 1942.
Flooding	Dec. 29, 1942	Dec. 31, 1942.
Reconstruction of washed-out dikes	Jan. 4, 1943	Jan. 11, 1943.
Unwatering, second time		Do.
Upstream crib arm		Jan. 15, 1943.
Removal	Jan. 30, 1943	February 1943.
Third-stage—closure:		
Final closure		Feb. 14, 1943.
Reservoir filling	Feb. 19, 1943	
QUARRY, CRUSHING, AND SIZING PLANT		
Quarry:		
Stripping	Feb. 3, 1942	
[illegible]	Feb. 18, 1942	
Drilling	Mar. 20, 1942	
First major blast	Early April 1942	
Production and storage of aggregate	Apr. 27, 1942	Mar. 13, 1943.
Stripping, quarry extension	June 10, 1942	
Plant:		
Garage, machine shop, compressor house, and office building.	Feb. 11, 1942	End February 1942.
Raw storage tunnel		Do.
Primary crusher		Apr. 22, 1942.
Secondary crushers (4)		End March 1942.
Rod mill		Do.
Stackers	Feb. 17, 1942	Do.
Conveyor system	March 1942	Apr. 27, 1942.
Dismantling of plant	Mar. 13, 1943	Apr. 10, 1943.
AGGREGATE PLANT		
Reclaiming tunnel:		
Excavation	Mar. 2, 1942	Mar. 14, 1942.
Concrete floor slab	Mar. 6, 1942	Apr. 3, 1942.
Timber arch	Mar. 20, 1942	Apr. 9, 1942.
Conveyor system:		
Timber tunnel under access road	Mar. 11, 1942	Mar. 16, 1942.
Excavation	Mar. 26, 1942	May 15, 1942.
Erection of supports:		
Conveyor No. 1	Mar. 28, 1942	Do.
Conveyor No. 2	Mar. 29, 1942	Do.
Conveyor No. 3	Apr. 1, 1942	May 16, 1942.
Conveyor No. 4	Apr. 6, 1942	Do.
Conveyor No. 5	May 5, 1942	May 25, 1942.
Mechanical installations	April 1942	May 1942.
Conveyor system in use		May 31, 1942.
Dismantling	June 18, 1943	July 1, 1943.
Rinsing-screen structure:		
Excavation	Apr. 9, 1942	
Erection	Apr. 13, 1942	May 12, 1942.
Dismantling	June 18, 1943	July 1, 1943.
MIXING PLANT AND CEMENT PLANT AREA		
Grading of site:		
Earth excavation	Feb. 1, 1942	Mar. 19, 1942.
Rock excavation	Apr. 17, 1942	Apr. 27, 1942.
CEMENT PLANT		
Cement silo and bucket elevators:		
Foundations	Mar. 30, 1942	Apr. 2, 1942.
Steel erection	Apr. 14, 1942	May 3, 1942.
Bucket elevator No. 1 in use		May 31, 1942.
Bucket elevator No. 2 in use		July 16, 1942.
Cement unloading pit:		
Excavation		End March 1942.
Concreting	Apr. 9, 1942	
Cement unloading shed and machinery:		
Erection	May 7, 1942	May 16, 1942.
First operation		May 28, 1942.

TABLE 9.—*Construction plant erection, in-operation, and dismantling dates*—Con.

Item	Started	Completed
CONCRETE-MIXING PLANT		
Auxiliary batching plant and cement storage	Apr. 9, 1942	Apr. 21, 1942.
Concrete substructure	Apr. 22, 1942	Apr. 28, 1942.
Steel erection	Apr. 29, 1942	May 23, 1942.
Mixer installation	May 4, 1942	May 28, 1942.
First operating test		May 29, 1942.
First concrete placed in dam		May 31, 1942.
Dismantling	June 28, 1943	July 20, 1943.
CONSTRUCTION BRIDGE		
Concrete substructure:		
North abutment	Apr. 6, 1942	Apr. 10, 1942.
Pier 14	Apr. 9, 1942	Apr. 13, 1942.
Pier 13	Apr. 12, 1942	Apr. 16, 1942.
Tower 12	Apr. 24, 1942	May 8, 1942.
Tower 11	May 6, 1942	May 29, 1942.
Tower 10	May 12, 1942	May 27, 1942.
Tower 9	May 13, 1942	Do.
Tower 8	July 17, 1942	July 28, 1942.
Tower 7	Aug. 9, 1942	Aug. 20, 1942.
Tower 6	Sept. 7, 1942	Sept. 23, 1942.
Tower 5	Sept. 28, 1942	Oct. 12, 1942.
Tower 4	Sept. 21, 1942	Oct. 17, 1942.
Tower 3	Sept. 13, 1942	Oct. 8, 1942.
Tower 2	Apr. 25, 1942	May 9, 1942.
Tower 1	do	May 15, 1942.
South abutment and gantry track extension	Oct. 28, 1942	Dec. 8, 1942.
Second gantry track extension	Feb. 12, 1943	Feb. 22, 1943.
	Completed [1]	Dismantled [2]
Steel structure, deck, and tracks:		
North abutment	Apr. 23, 1942	July 31, 1943.
Pier 14	Apr. 26, 1942	July 24, 1943.
Pier 13	May 23, 1942	July 23, 1943.
Tower 12	June 1, 1942	June 29, 1943.
Tower 11	June 7, 1942	May 3, 1943.
Tower 10	June 14, 1942	May 1, 1943.
Tower 9	June 23, 1942	Apr. 29, 1943.
Tower 8	Aug. 8, 1942	Apr. 26, 1943.
Tower 7	Sept. 20, 1942	Apr. 24, 1943.
Tower 6	Oct. 5, 1942	Apr. 22, 1943.
Tower 5	Oct. 19, 1942	Apr. 16, 1943.
Tower 4	Oct. 26, 1942	Apr. 12, 1943.
Tower 3	Nov. 2, 1942	Apr. 8, 1943.
Tower 2	Nov. 6, 1942	Apr. 5, 1943.
Tower 1	Nov. 28, 1942	Mar. 31, 1943.
South abutment and gantry track extension	Dec. 8, 1942	Mar. 27, 1943.
Second gantry track extension	Feb. 24, 1943	Do.
	Started	Completed
Timber approach trestle:		
Trestle	May 29, 1942	June 30, 1942.
Service track		Aug. 1, 1942.
	Placed in use	Dismantled
Revolving gantry cranes (40-ton):		
First Clyde crane	Apr. 14, 1942	Mar. 7, 1943.
Second Clyde crane	May 30, 1942	Aug. 4, 1943.
Dravo crane	July 25, 1942	Apr. 14, 1943.
American crane	Nov. 23, 1942	Apr. 8, 1943.
Stiffleg derrick	June 12, 1942	Mar. 13, 1943.
	Started	Completed
DAM AND POWERHOUSE		
[illegible]	Jan. 30, 1942	February 1942.
[illegible]		
[illegible]rth side	Jan. 29, 1942	
Diamond drilling, south side	Feb. 20, 1942	
Auger borings	Jan. 29, 1942	

[1] Erection of bridge started at the north abutment and progressed south as indicated by date shown.
[2] Dismantling of bridge began at the south end and progressed north as indicated by dates shown.

Table 9.—*Construction plant erection, in-operation, and dismantling dates*—Con.

Item	Started	Completed
DAM AND POWERHOUSE—continued		
Excavation:		
North nonoverflow section	Feb. 1, 1942	
Spillway and south nonoverflow section	February 12, 1942	November 1942.
Intake and powerhouse	April 1, 1942	
Concrete placing:		
Main pours	May 31, 1942	March 22, 1943.
Essentially completed		July 1943.
Switchyard	September 18, 1942	November 1943.
High-pressure grouting	May 1942	July 1943.
Rolled fill, switchyard	July 1942	August 1942.
Saddle dams (Nos. 1 to 10, inclusive):		
Stripping	March 20, 1942	Do.
Rolled fill	April 21, 1942	Do.
Foundation grouting	April 1942	August 1943.
Riprap	June 24, 1942	November 1942.
Reservoir water storage	February 19, 1943	
Unit No. 3 on the line		March 1943.
Landscaping	February 1943	November 1943.

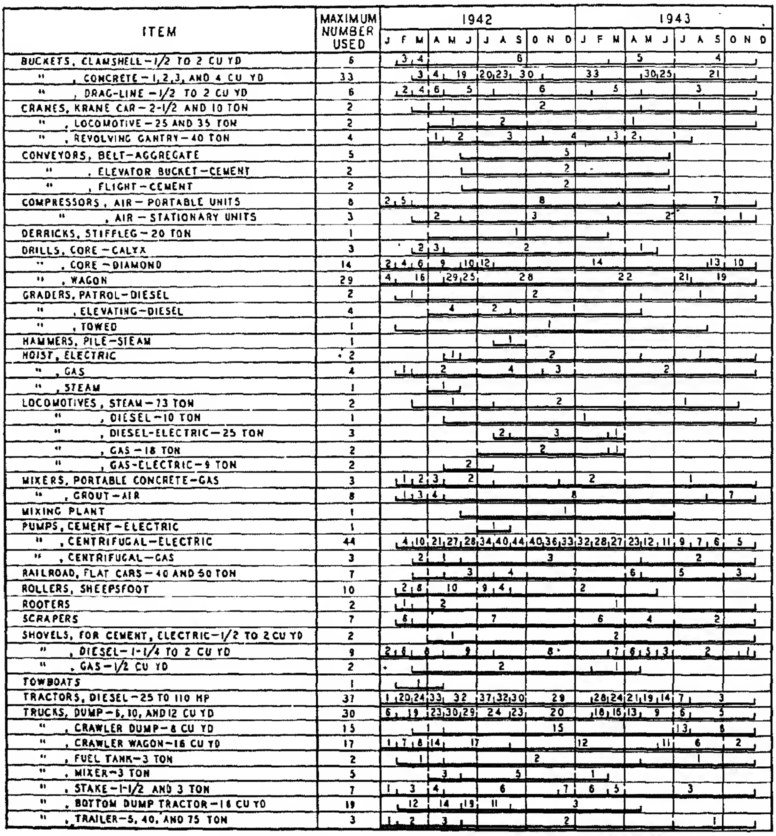


Figure 49.—*Schedule of major construction plant equipment usage.*

ACCESS

Highway access

On both sides of the river, access highways were built to serve the construction area. The access roads were 31 feet wide at subgrade and were surfaced with a bituminous top, 22 feet wide, on a stabilized crushed-stone base 6 inches thick.

The north access road connected to the Kykers Ferry-Dandridge Road at a point approximately 7½ miles west of Dandridge. From Douglas powerhouse to the junction between these two roads was a distance of slightly more than 1 mile. About 2,000 feet from this junction, the access road crossed the road between the trailer camp and the main construction camp. Three hundred feet farther, a road turned to the main camp and the administration building (see fig. 45). Approximately ¾ mile from the junction, the access road branched in two directions. One road turned east, passed by the compressor house, and then continued to the mixing-plant area and the powerhouse; the maximum grade on this road was 9.5 percent on a 200-foot long stretch. The other road turned south to the temporary access bridge over the river; the maximum grade was 10 percent for a short distance of 200 feet; the average grade was approximately 7.4 percent. Where this road connected with the access bridge, a side road turned to the shop area, and another connected to the dike around the stockpile.

The south access highway, which connected the access bridge with the Sevierville-Dandridge county road, was 1.2 miles long. From the south end of the access bridge the road followed the railroad for about 700 feet and then turned away from the river to its junction with the county road.

TABLE 10.—*Cost of construction plant and equipment*

Description	First cost to Douglas Dam	Salvage—sales and transfers	Net cost to Douglas
[illegible]	$799,429	$597,249	$202,180
[illegible] equipment	48,703	39,420	9,283
Special job trackage	7,731	39	7,692
Construction trestle	712,929	51,083	661,846
Drilling equipment	24,943	19,963	4,980
Unassigned nonrated drilling equipment	74,192	43,738	30,454
Excavating, grading and surfacing equipment	210,837	161,957	48,880
Unassigned nonrated excavating, grading, and surfacing equipment	45,584	31,847	13,737
Untagged excavating equipment accessories	4,776	3,929	847
Rated hoisting equipment	125,973	89,245	36,728
Unassigned nonrated hoisting equipment	16,111	10,618	5,493
Nonrated untagged unwatering equipment	76,461	53,893	22,568
Miscellaneous untagged cofferdam, plant, and unwatering equipment	2,605	581	2,024
Nonrated marine equipment	1,087	990	97
Reclaiming tunnel	55,916	1,338	54,578
Aggregate conveyors and screens	106,053	24,678	81,375
Cement plant assembly	59,137	10,483	48,654
Unassigned nonrated concrete plant	73,645	34,192	39,453
Concrete mixing plant	148,859	25,326	123,533
Untagged miscellaneous concrete and form-handling equipment	4,705	2,737	1,968
Rated miscellaneous equipment	774	1,250	[1] 476
Nonrated miscellaneous equipment	23,289	16,255	7,034
Transformers	28,387	23,920	4,467
Untagged miscellaneous equipment	2,707	2,310	397
Miscellaneous electrical instruments	611	316	295
Total, construction plant and equipment	2,655,444	1,247,357	1,408,087

[1] Denotes credit.

TABLE 11.—*Cost of operating excavating and hauling equipment*

Equipment	Number	Hours worked (net)	Cost per net operating hour				
			Operation	Repairs	Erect and dismantle	Depreciation	Total
Shovels:							
2-cubic-yard Diesels	5	34,175	$5.028	$3.400	$0.132	$0.858	$9.418
1½-cubic-yard Diesels	4	17,473	5.141	4.477	.485	.032 [1]	10.071
½-cubic yard Diesels	2	9,626	4.065	1.016	.151	.571	5.803
Stiffleg derrick operation	1	637	7.877	.015	16.148	4.658	28.698
Trucks:							
12-cubic-yard Hug dump	12	15,350	3.414	4.259	----------	.765 [1]	6.908
6-cubic-yard Federal dump	4	1,019	3.718	5.304	----------	1.282 [1]	7.740
12-cubic-yard Sterling dump	5	4,074	3.179	2.122	----------	2.211	7.512
9.7-cubic-yard Euclid end dump	9	17,361	3.171	2,231	----------	.262 [1]	5.140
6-cubic yard White dump	4	22,247	2.256	.750	----------	.422	3.428
2-cubic yard transit mix	5	6,683	2.093	1.078	----------	.245	3.416
Koehring dumpsters	6	15,084	1.997	.636	----------	.974	3.607
Tractors:							
96-horsepower caterpillar D8	25	126,956	3.032	2.531	----------	.062 [1]	5.501
96-horsepower a. c. HD14	3	11,796	2.532	1.606	----------	.630	4.768
Cletrac FDLC	7	10,554	3.566	3.740	----------	.168	7.474
Linn crawler-type dump trucks	15	76,516	2.330	1.453	----------	1.553	5.336
Euclid trak-truck, 13-cubic-yard	19	24,125	3.004	2.841	----------	.573	6.418
Elevating grader:							
Caterpillar No. 48	2	4,303	3.869	2.362	----------	1.133	7.364
Adams, No. 11	2	1,700	5.201	2.969	----------	2.734	10.904
Crawler wagons,[2] Athey 16-cubic-yard	17	43,860	.474	.292	----------	.675	1.441
12-cubic yard carry-all, LeTourneau	7	7,572	.428	.739	----------	.542	1.709

[1] Credit. [2] Tractor-drawn. No operator required.

Railroad access

The access railroad was 5.6 miles in length from its junction with the Smoky Mountain Railroad at Ewing, Tenn. It crossed the Little Pigeon River on a single-track bridge consisting of three steel girder spans and timber approach trestles. The steel spans were old bridges purchased from the Louisville & Nashville Railroad Co. There were one 50-foot-long through girder span weighing 85,000 pounds and two 38-foot-long deck girder spans weighing 34,000 pounds each.

The contract between the TVA and the Smoky Mountain Railroad Co. specified that the TVA pay the railroad $42,500 for rehabilitation of its line between Knoxville and Ewing and lend it one of the steam locomotives (73 tons) from Cherokee Dam, in lieu of which the railroad would haul the trains from Ewing to the storage sidings located on the left bank of the river about a mile from the dam. From these sidings, cars were hauled to the plant area on the opposite side of the river by TVA owned and operated 73-ton steam locomotives. After crossing the bridge, railroad cars could either be moved to the cement silo or the shop area. The track to the cement unloading point at the silo and to the construction bridge was on a 2.64 percent maximum upward grade. The track to the shop area was on a 2.26 percent maximum downward slope. There were sidings to the carpenter shop, to the machine shop, to the warehouse, and to the oil storage so that cars could be brought directly to their destination.

Because of the limited space in the shop area much of the material and equipment was temporarily stored along the storage sidings on the south bank. This was the case with the structural steel for the access bridge and for the construction bridge. Transportation from this storage yard to the dam was by truck, by trailer float, or by railroad car.

Locomotive and job railroad operating costs are given in tables 12 and 13.

TABLE 12.—*Locomotive operation costs*

Item	75-ton, coal burning	18-ton, gas-electric	25-ton, Diesel electric
Pieces of equipment, number	3	3	3
Hours operated, net	4,884	11,413	9,910
Operating labor	$4.505	$1.786	$2.187
Fuel:			
Coal (1,808 tons)	1.399		
Gasoline (22,885 gallons)		.199	
Fuel oil (2,184 and 11,702 gallons)		.016	.096
Miscellaneous supplies and expense	.576	.035	.044
Repairs	2.047	.376	.254
Erect and dismantle	.147	.002	.036
Depreciation	.519	.578	.733
Total cost	9.193	2.992	3.350

TABLE 13.—*Job railroad operation*

[4,405 cars]

	Cost per car
Operating labor (switchmen, etc.)	$3.536
Equipment operation (steam locomotive)	11.239
Repairs to cars	.066
Repair and maintain tracks	4.574
Depreciation:	
Plant railroad	26.716
Railroad cars	.143
Total cost	46.274

Access highway and railroad bridge

The highway and railroad bridge, which provided access during construction, across the French Broad River was located approximately 2,100 feet downstream from the dam (see fig. 50). The structural steel bents and deck girders were obtained from the aggregate trestle at Cherokee Dam and transported by truck and trailer float. Most of the deck steel and all of the bents required some alterations which were done at Douglas Dam. The bridge was 766 feet and 5½ inches long, measured from end to end of steel. Beginning at the north end, the first 12 spans (or 458 feet) were built on a straight line; the remaining 8 spans were constructed on a 14° curve.

The bridge was level for the first 15 spans from the north end with the top of bridge floor at elevation 910; the remaining 5 spans were on a one-half percent grade down toward the south abutment. The superstructure consisted of 20 steel spans with timber decking. Three of these spans were 30 feet long, the others varied in length from a little below to a little above 40 feet. The substructure consisted of a timber-crib abutment at each end and 19 steel bents. All bents were rigid type frames fabricated with horizontal struts but without cross bracings (see fig. 51). Six of the bents were braced together longitudinally, in groups of two, to form three towers. All the bents were supported on timber cribs, except four on the south bank which rested on concrete footings.

The bridge was designed to carry one lane of traffic, either railroad or highway, and walkway loading. The railroad loading was assumed to consist of one 73-ton steam locomotive hauling 85-ton freight cars. Fifty percent impact was allowed and a braking force equal to 7½ percent of the train load (without impact) was permitted. This limited the maximum speed of the train to 5 miles per hour. The design of the timber deck was controlled by the wheel loads of a 23-cubic-yard tournapull. These loads amounted to 35,500 pounds plus 25-percent impact on each rear wheel. The bridge was strong enough to carry a 2-cubic-yard shovel weighing 80,000 pounds after counterweights, dipper, and dipper stick had been removed. It was designed to withstand a 70-mile-per-hour wind, when empty, equivalent to 30 pounds per square foot on 1½ times the projected area of the structure; or a 40-mile-per-hour wind, when loaded, equivalent to 10 pounds per square foot on 1½ times the projected area of the structure, with 60 pounds per linear foot on train applied 6 feet above top of rail. The walkway was designed for a live load at 100 pounds per square foot.

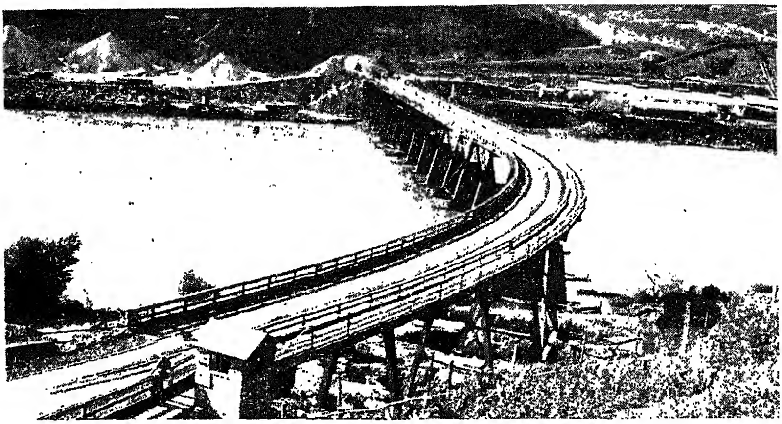


FIGURE 50.—*Highway and railroad access bridge from south bank.*

The bridge deck (see fig. 52) was built new and consisted of 12-inch timber ties, 16 feet long, spaced 14 inches on centers. These timbers supported the two rails (85-pound ASCE) and the floor planks for the 14-foot-wide roadway. These floor planks were laid in two layers, first a 3-inch subfloor laid diagonally, and above this a 3-inch wearing surface, consisting of white oak No. 1 bridge planks, and laid longitudinally. On each side of the road was a timber curb and heavy timber railing. The planks were fastened with 50d nails, two at each tie.

The timber deck was supported by two wide-flange steel beams spaced 7 feet 8 inches on centers. The 40-foot spans consisted of two 36-inch wide-flange beams weighing 160 pounds per foot. The top flange was reinforced with a 15-inch channel weighing 33.9 pounds per foot. The beams were tied together with three diaphragms, one at each end and one at the center of the span. These diaphragms were fabricated from 18-inch wide-flange beams, weighing 50 pounds per

foot. No horizontal bracing was provided. The 30-foot spans consisted of two 36-inch wide-flange beams weighing 150 pounds per foot. The beams in each span were tied together with the same type and number of diaphragms as the 40-foot span, and with horizontal bracing consisting of 4- by 4- by 5/16-inch single angles welded to existing gusset plates on the top flange of each beam.

The 5-foot walkway was built of 2-inch planks supported on two wide-flange steel beams, 3 feet on centers, and supported on cantilever brackets riveted to the upstream columns of the bents.

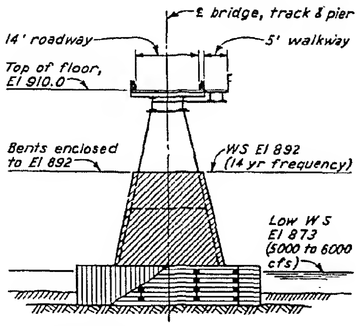


FIGURE 51.—*Typical section through highway and railroad access bridge.*

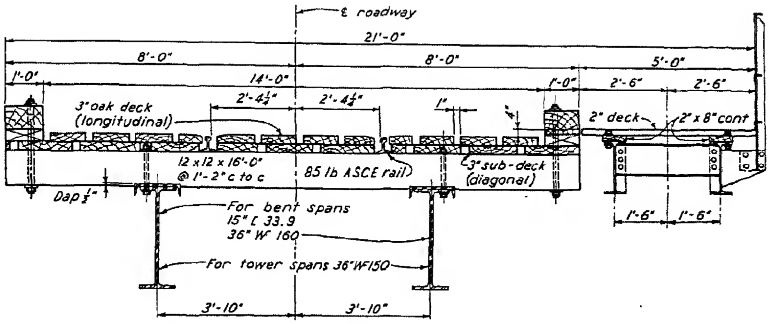


FIGURE 52.—*Access bridge—Details of deck structure.*

Provision for expansion was provided at the two abutments and on the south side of each tower. All other connections between spans and bents were fixed. The bents were too high, and it was necessary to cut the columns. For 13 of the bents the upper part of the original bents was used, and only new column bases had to be fabricated and put on. For the six bents used in the towers the lower part of the original bents was used, and holes had to be drilled for cap beam and longitudinal bracing connections. Each bent was 8 feet wide at the top and all columns had a batter of 2½ in 12.

The timber cribs which supported the bents were built to elevation 873±, which permitted a discharge of 6,000 cubic feet per second during their construction. They rested on rock and were constructed of

FIGURE 53.—*Access bridge. Excavation for crib foundation.*

8- by 8-inch timbers drifted together with ¾-inch-round pins. They were built with pointed ends to reduce the velocity pressure and any tendency to accumulate floating trash and were divided into three compartments. The center compartment was filled with rock and the end ones with concrete. The bents were anchored to the concrete with two 1½-inch-diameter anchor bolts at each column, except the tower bents, where four 2¼-inch-diameter bolts were used at each column. All anchor bolts were set in pipe sleeves. The original design called for 6-foot-wide cribs 40 feet long for the single bents, but after four of these had been built the cribs were increased to the same size as the tower cribs to obtain better stability on the rough river bed; these were 8 feet wide and 43 feet and 6 inches long. The cribs were covered with 1-inch sheathing and the upstream nose was protected by a 10-gage bent-steel plate 6 inches wide.

The two rock-filled crib abutments were constructed of 8- by 8-inch timbers. The north abutment was built with skew stepped-down wing walls, the south abutment without wing walls. The bridge seats consisted of 4-foot-wide by 11.67-foot-long concrete slabs, 2.5 feet deep, which were supported on timber posts to rock.

The bridge was erected in the following manner. Work first started with excavation for the north abutment. Excavation was carried to rock, and the overburden material was used to form part of the protective dike around the aggregate stock-pile area. On the south bank, excavation to bedrock for the abutment and for the footings of the adjacent four bents was done with a ½-cubic-yard dragline.

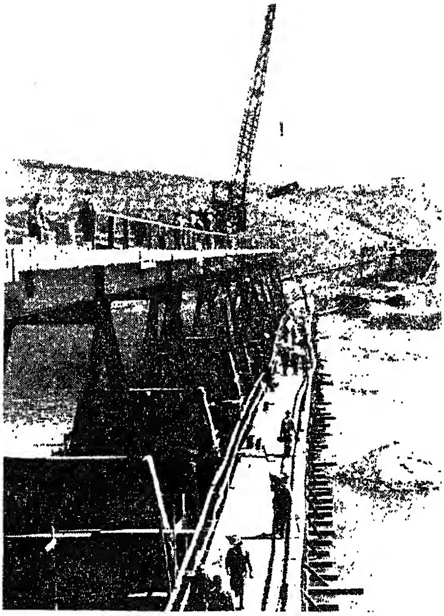


FIGURE 54.—*Access bridge during construction.*

Excavation in the river for the timber cribs supporting 12 bents was carried to bedrock with a ½-cubic-yard clamshell bucket operated from a crane mounted on a pontoon float (see fig. 53). A heavy steel cable was stretched across the river from bank to bank, approximately 100 feet upstream from the bridge location. The pontoon barge was held in position by steel ropes attached to this cable.

All timber cribs for the bents were built on the north bank of the river and pulled into the water with block and tackle. Fastened between two timber barges, the crib was then maneuvered into its proper location with gasoline launches and held in place with guy cables while the crib was lowered in place by filling it with rock. The rock was hauled out in wheelbarrows over a temporary timber runway constructed on top of the cribs. When sufficient rock had been placed to insure against movement of the crib, concrete was placed by tremie in the end compartments. Concrete was mixed in a portable mixer and placed with wheelbarrows. After completion of concrete placing, jackhammer holes were drilled through the concrete and grout and a cement sand mixture was poured into these holes to further stabilize the cribs. The concrete footings for the four bents at the south end were placed by chutes from a portable mixer.

Steel erection started at the north abutment. From this abutment to bent 14, inclusive, steel was handled with a crawler crane (see fig. 54). The bridge steel from the south abutment to bent 14 was erected with a locomotive crane.

CONSTRUCTION BUILDINGS

To avoid delays in construction no new designs or details of buildings were developed. New buildings were constructed from plans prepared previously for other TVA projects. Several smaller job buildings were transferred from Cherokee Dam. The warehouse and the machine shop had to be built new as none were available within the TVA. Temporary offices, a warehouse, and a tool room were built immediately and completed during February 1942, the first month of construction; the compressor house was completed March 26, 1942, though it was placed in service some time before March 15, 1942; and practically all other buildings were finished and in use before the end of April 1942.

In the main yard or shop area, which was about 1,200 feet long and 350 feet wide, the following shop buildings and job buildings were located: warehouse, machine shop and garage, carpenter shop, oil house (with one gasoline tank and three oil tanks), bag-cement house, field engineers' office, two first-aid buildings, and numerous 20- by 20-foot job buildings (see fig. 55). The small job buildings were used by riggers, carpenters, electricians, pipefitters, foremen, and truck dispatchers; or to house tools, a water cooler, and a tin shop. After the first-stage cofferdam had been completed, most of the small job buildings were moved down in the coffer area to be near the construction activities. Just before the cofferdam was removed they were again moved to the shop area and located along the river bank.

The compressor house was located along the road to the mixing plant area above the shop area. The administration building on top of the hill commanded a full view of the construction area.

The time office and a small sandwich shop were located where the road to the administration building turned off the north access road. The hospital and personnel building was built nearby and the ex-

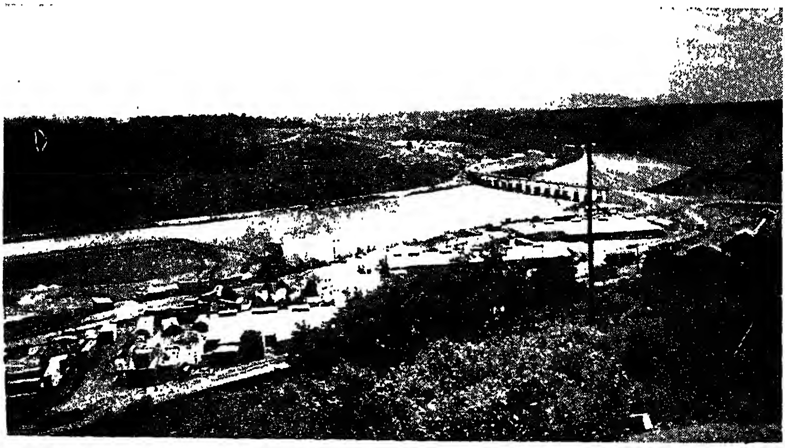


FIGURE 55.—*Construction plant shop area.*

plosives house was erected near the storage yard, some distance back of the hospital.

The substation that served the construction area was erected not far from the time office; the other substation, built by the TVA near the quarry, provided electric power for the aggregate contractor. Both substations were located on high ground far above the highest river level recorded.

The buildings were wooden frame temporary structures. They were all founded on mud sills, except the first-aid building, the field engineers' office, the reinforcing yard office, the riggers' shack, the tool shanty, and the 20- by 20-foot job buildings which were on skids to facilitate moving them around in the construction area. The buildings were only one-story high with the exception of the administration building which had two stories and a basement. The main shop and plant buildings, such as warehouse, machine shop, carpenter shop, compressor house, oil house, and cement shed were covered with corrugated or V-crimp galvanized steel siding and roofing, while the smaller buildings were built with shiplap siding and with either asphalt shingles or three-ply roll roofing.

The administration building, the hospital and personnel building, and the various camp buildings are discussed in chapter 5.

The general dimensions of various plant buildings are listed in table 14. Buildings and utilities costs are given in table 15.

Table 14.—*General dimension of plant buildings*

Type of building	Length in feet	Width in feet	Wings, platforms, or other additions
Administration building (3-story)	76	36	
Health and safety building			
Hospital and personnel building	90 51	33 33	36- by 33-foot wing, hospital. 21- by 30.5-foot wing, personnel.
Time office	40	24	1 24- by 19-foot platform. 1 9- by 19-foot platform. 1 13.5 -by 19-foot platform.
Carpenter shop	104	36	14- by 80-foot lean-to. 80- by 108-foot platform. 20- by 48-foot platform.
Compressor house	60	28	
Concrete-testing laboratory	20	20	
Detonator house	10.5	10.5	
Explosives house	26.5	18.5	
[illegible]	30	16	
[illegible]	24	12	
[illegible]			
Machine shop [2]	210	50	31- by 14-foot locker room.
Miscellaneous shop and job buildings [1]	20	20	
Oil house and storage	80	20	
Reinforcing yard office [1]	16	10	
Riggers' shack [1]	52	20	Two 20- by 20-foot buildings with 32-foot extension.
Substation, main construction	30	16	
Substation at quarry	24	16	
Telephone exchange building (temporary)	12	12	
Tool shanty [1]	16	10	
Warehouse	195	60	15- by 60-foot screened-in platform.

[1] Building was founded on skids.
[2] Timber roof trusses were used to expedite completion of shop.

TABLE 15.—*Buildings and utilities costs*

Description	First cost to Douglas Dam	Salvage sales and transfers	Net cost to Douglas
General site preparation	$77,802	------------	$77,802
Construction roads, bridges and drains	236,625	$1,036	235,589
Telephone system	4,882	789	4,093
Fresh-water supply system	29,036	4,936	24,100
Raw-water system	73,840	11,832	62,008
Sewer system	5,379	104	5,275
Electric system	83,138	19,643	63,495
Fire- and police-alarm system	21,484	275	21,209
Compressed-air system	72,602	35,898	36,704
Standard-gage plant railroad system	128,005	10,323	117,682
Main office	33,026	2,990	30,036
Engineers' field office	2,399	------------	2,399
Time office	6,626	497	6,129
Warehouse and storage yard	47,105	6,221	40,884
Testing laboratory	4,452	3,536	916
Tool house	229	105	124
First-aid stations	1,814	91	1,723
Temporary toilets	5,948	141	5,807
Miscellaneous small buildings	58,792	6,657	52,135
Machine and general shop	64,894	24,029	40,865
Carpenter shop	34,623	11,654	22,969
Electrical shop	340	------------	340
Garage	3,562	23	3,539
Lunchroom	828	187	641
Steel-bending shop	2,541	1,939	602
Pipe shop	2,388	1,580	808
[illegible]	3,689	3,689	------------
[illegible]d facilities	38,462	161	38,301
Total, buildings and utilities	1,044,511	148,336	896,175

UTILITIES

Drains

All roads in the shop area were graded and surfaced with crushed rock. Pipe drains were laid in the construction plant area as shown in figure 45.

Filtered water

The filtered water system is described in chapter 5.

Raw water

The raw-water system consisted of a 50,000-gallon-capacity elevated steel storage tank transferred from Cherokee Dam, two electric-driven vertical centrifugal pumps at the system intake, and a network of distribution lines. The storage tank was located on the hill opposite the road from the administration building. The 22-foot-diameter tank was supported on a 105.5-foot-high tower with a balcony at the top. A standard 10-inch-base ell and a 36-inch riser were provided.

The raw water was taken directly from the French Broad River. Actually, three pumps were transferred from Cherokee Dam but one was held as a spare. Each pump was rated at 1,200 gallons per minute at 450-foot head and driven by a 200-horsepower, 2,200-volt, 3-phase, 60-cycle, vertical squirrel-cage induction-type motor. These pumps were first located on a log crib intake structure (see fig. 56) on the north bank of the river approximately 1,200 feet downstream from the dam. The rock fill was obtained from excavation in the mixing plant area. The first pump was put in service on March 17 to supply the main air compressor, although the raw-water tank was not completed and filled until later. The second pump was installed after the raw-water storage had been completed.

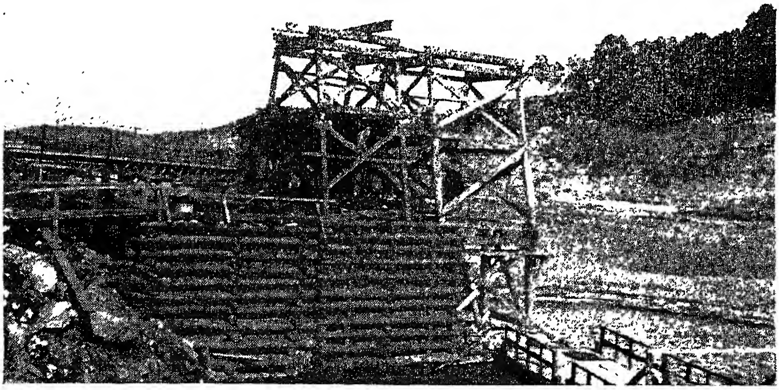


FIGURE 56.—*Raw water intake pumping station.*

In September 1942, the pumps were moved to the upstream face of the dam, inside the first-stage cofferdam, and served not only in supplying raw water but also assisted in pumping out the cofferdam until its removal. During the first week of December 1942, the pumps were again moved, this time to unit 4 in the powerhouse. They remained there until completion of the job. The main raw-water distribution system consisted principally of 8-inch pipes, though some 12- and 6-inch lines were used. When the pumps were located on the log crib structure on the right bank a 12-inch pipe 100 feet long connected the pumps with two 8-inch mains to the raw-water tank. One of the mains was laid between the warehouse and the machine shop and then continued up the hill to the tank; the other line was laid past the carpenter shop and the mixing plant, then up the hill to the tank. An 8-inch line across the construction bridge joined the latter main near the mixing plant. Several 6- or 8-inch branch lines from the two mains were laid to the various job buildings. Twenty 4-inch fire hydrants rated for 250-pound water pressure and with two 2½-inch hose connections were scattered through the shop and mixing plant area and near the administration building. All pipe lines were protected against damage by frost, pipes in the ground by 3 feet of cover, pipes above the ground by other means. All pipe lines were specified to be either level or sloping upward toward the tank to avoid air pockets. Where this could not be done air relief valves were provided.

All pipes 6 inches and over were spiral welded and coated inside and outside with coal tar pitch varnish. Pipes were ordered in 40-foot lengths, ends suitable for welding, and butt-welded together in the field into 120-foot sections. These sections in turn were joined by Dresser-type couplings, the welded beads having been ground off each end of the pipe for a distance of 10 inches.

All valves were standard flanged ferrosteel body wedge-gate type, with nonrising stem, brass seats, and brass stem. Fittings were 250-pound cast-iron flanged.

Compressed air

The first 7 weeks before the main compressed-air plant had been installed and placed in service air was supplied to drilling operations by portable compressors. On the south bank five portable compressors with a total capacity of 1,760 cubic feet per minute were used; on the north bank three portable compressors with a total capacity of 1,000 cubic feet per minute were in operation.

The main compressed-air plant (see fig. 57) consisted in the beginning of two Sullivan twin-angle compound air compressors, each having a piston displacement of 3,148 cubic feet per minute and each driven by a 500-horsepower synchronous motor complete with dead front and totally enclosed starters and 15-kilowatt motor generator exciter. Each compressor was furnished with a size M–12 aftercooler and an Air-maze oil-bath-type air filter. A single 66-inch-diameter air receiver 30 feet long was used. The compressor plant was originally purchased for Cherokee Dam, then transferred to Douglas Dam. More specific data on the compressor plant include:

Compressors: Sullivan class WN–4, sizes 22 by 14 inches and 13 by 14 inches.
Motors: Electric Machinery & Manufacturing Co., 500-horsepower motor, 257-revolution-per-minute, 2,300-volt, 3-phase, 60-cycle, with 0.8 power factor.
Aftercooler: Sullivan, multipass, No. 12.

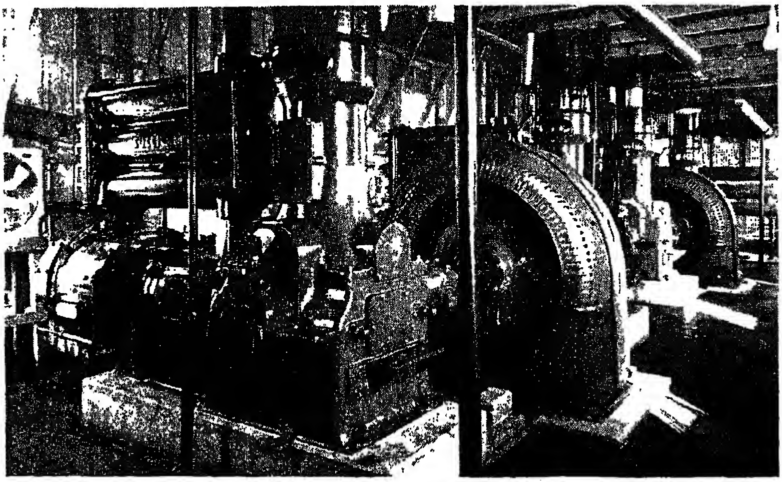


FIGURE 57.—*Main compressed-air plant.*

The compressors were located 24 feet and 2 inches apart and enclosed in a building 28 feet wide and 60 feet long. The air receiver and the air filters were located outside on the north side of the building. In June the compressor house was extended 12 feet, and a 1,400-cubic-foot-per-minute Bury compound compressor, transferred from Fort Loudoun Dam, was installed July 1, 1942, to help take care of peak loads. This Bury compressor, class VCC–4–B, had a 1,420-cubic-foot-per-minute maximum piston displacement under full load, two low-pressure cylinders 16 by 16 inches, one high pressure cylinder 14 by 14 inches, and a maximum speed of 225 revolutions per minute.

It was belt driven by a 250-horsepower General Electric induction motor, 450 revolutions per minute, 440 volts, 60 cycles. A Sullivan, serial 123, aftercooler and one American type 4–SCF air filter were used with this compressor.

The main distribution system consisted of a 10-inch main from the compressor plant along the road toward the mixing plant and continuing out upon the construction bridge. A 2-inch branch extended to the reclaiming tunnel under the stock pile, a partly 4-inch and partly 2-inch branch went to the carpenter shop, and a 4-inch line supplied air to the mixing plant and the cement silo. Before the construction bridge had been extended to the south bank, a 6-inch main was laid on top of the entire first-stage cofferdam. A 4-inch branch line from this 6-inch main was carried across the first-stage diversion channel by means of a steel suspension cable to provide air for operations in the south abutment area. Smaller lines were tapped into the main distribution system wherever needed.

Where required, 2-inch wedge disc, nonrising stem, standard 125-pound steam, brass gate valves, and 3- to 10-inch standard iron body wedge-gate valves, flanged types, were installed.

On the line to the mixing plant area a 36-inch-diameter vertical air receiver, 8 feet long, and a 4-inch moisture separator complete with automatic drain trap were installed. Air traps of the inverted-bucket type, Armstrong No. 213, were placed below the 10-inch air main at all low points.

All pipe 4 inches or more in diameter was spiral welded with No. 12 USS-gage wall thickness. It was ordered in 40-foot lengths similar to that used for the raw-water system. Some pipe was purchased coated inside and outside, same as the water pipe.

Sanitary sewer systems

The sanitary sewer systems extended throughout the camp and construction plant area. One system served the trailer camp, the hospital, the main camp, and the administration building. Sewage from this system emptied into the main septic tank located about 200 feet northeast of the administration building. This tank was built of reinforced concrete and had a capacity of 38,000 gallons. The outfall line from this tank passed through the shop area and emptied into the river below the raw-water intake station. In this system 6,260 feet of 6-inch pipe and 2,140 feet of 8-inch pipe were used. Vitrified clay sewer pipe was used throughout the job. Standard brick manholes were built wherever the sewer lines changed direction or slope.

A separate small reinforced concrete septic tank of 900-gallon capacity was built at the time office; because it was about 35 feet lower than the main septic tank, connection to the main system was impossible.

Another sewer system served the compressor house and the buildings in the shop area. The mains in this system consisted of 815 feet of 10-inch pipe, 654 feet of 12-inch pipe, and 400 feet of 15-inch pipe. In addition 1,050 feet of 6-inch branch sewers were installed. The system emptied into the river downstream from the raw-water intake station. Manholes were similar to the ones for the camp sewer system.

Gasoline, fuel oil, and lubricants

Diesel fuel oil and gasoline were delivered in railroad tank cars to the job and stored in four horizontal steel storage tanks supported on

steel bents and concrete piers. Gasoline was stored in one 12,000- and two 15,000-gallon tanks. Diesel fuel oil was stored in one 12,000-gallon tank. One of the 12,000-gallon tanks was transferred from Watts Bar Dam, the other tanks from Cherokee Dam.

Lubricants in drums were stored in an oil shed located in the shop area near the access bridge. This building was 20 feet wide and 80 feet long. It consisted of a 40-foot-long storage room with crushed rock floor and a 40-foot screened-in and roofed-over wood platform. In the storage room two rows of drums were stored on timber racks, and smaller quantities of kerosene, varsol, and various lubricants were obtained from these. If a full drum was needed it was delivered from the platform.

All construction equipment was serviced by two tank trucks and two grease trucks. The tank trucks were 3-compartment 650-gallon capacity GMC trucks; one truck was transferred from Cherokee Dam, the other was purchased new for Douglas Dam. One of the grease trucks was a 4-ton International D–50 model stake truck transferred from Cherokee Dam, the other was a stake truck obtained from the TVA's transportation equipment pool. On the grease trucks the following accessories were mounted:

One garage-type gas-engine-driven air compressor of 20-cubic-foot-per minute capacity.
One 20-inch-diameter air receiver 6 feet long.
Three water tanks, made of 6-inch-diameter spiral welded pipe, 14 feet long.
One drum for high-pressure grease, One drum for transmission grease, One drum for hoist oil } on other side of the truck.
Two spare drums at center of truck.
Alemite oil dispensers, and Alemite high- and low-pressure pumps.
Six reels with oil and grease hoses at the rear end of the truck. (Two reels served the high pressure grease drum, none connected to the hoist oil drum, and one reel was provided for each of the other drums.)
Two reels with air hoses, one on each side of the truck.
Three water tanks, made of 6-inch-diameter spiral welded pipe, 14 feet long. These were mounted below the truck bed.
All drums were standard 55-gallon size.

One grease truck and one fuel truck worked together as a unit and performed all services on a piece of equipment in a single stop. The grease truck also serviced trucks and cars, changing oil, putting air in tires, and refilling radiators.

Electrical power

Incoming power.—On February 8, 1942, construction power was made available at the dam site. Telephone service was established at the dam site on February 9. Construction power for Douglas Dam was taken from the Sevierville substation which had an ultimate capacity of 9,000 kilovolt-amperes when using fans for cooling the transformers. Two 12.45-kilovolt circuits from the Sevierville substation served the project, one of aluminum construction with a capacity of 3,000 kilovolt-amperes, the other a copper circuit having a capacity of 7,000 kilovolt-amperes, giving a total line capacity of 10,000 kilovolt-amperes for both circuits. A tap structure with two circuits to the dam site was erected. One tap circuit having a capacity of 7,000 kilovolt-amperes served the main construction substation.

The other tap circuit served a 1,500 kilovolt-ampere substation which furnished power to the aggregate contractor at the quarry site. The two main circuits from the Sevierville substation to the tap structure were operated in parallel. Disconnecting switches were installed at both ends of these two lines and permitted either line to be removed from service in the event of trouble. The tap structure was built with two sets of disconnecting switches connected to a common bus from which two additional sets of disconnecting switches were connected for the two tap circuits to the project.

Substation.—The main construction substation consisted of three 1,000 kilovolt-ampere, 12.45-kilovolt to 2.4-kilovolt oil insulated, self-cooled transformers located on the right bank of the river downstream from the dam site at elevation 1,080 (see fig. 58). An exceptionally heavy pumping load caused by leaks in the cofferdam required the addition of two 667 kilovolt-ampere transformers connected in open delta, and at a later date this open delta was closed with two 400 kilovolt-ampere transformers connected in parallel.

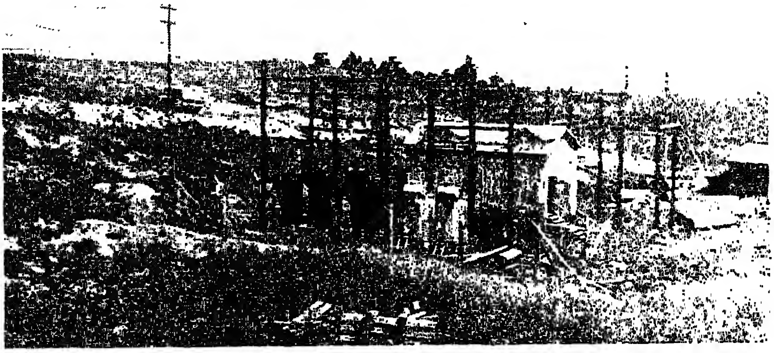


FIGURE 58.—*Main substation.*

The switch house contained a 2,300-volt switchboard consisting of one main line panel and seven feeder panels. Disconnecting switches were provided for each panel. The main line panel consisted of a manually operated 1,200-ampere, 3-pole, 50,000-kilovolt-ampere interrupting capacity, oil circuit breaker; a voltmeter; an ammeter; voltmeter and ammeter transfer switches; and a watt-hour meter. All meters and switches were mounted on a sheet steel panel 24 inches wide and 76 inches high.

Each feeder panel consisted of a manually operated 600-ampere, 3-pole, 50,000-kilovolt-ampere interrupting capacity, oil circuit breaker; an ammeter; an ammeter transfer switch; and a watt-hour meter. These meters were also mounted on sheet steel panels 24 inches wide and 76 inches high.

Electrical distribution.—The electrical distribution system consisted of five 2,200-volt, 3-phase circuits. Transformer banks were

provided at various locations for stepping the voltage down to 110, 220, or 440 volts as required. All equipment in the carpenter shop and machine shop was designed for 220-volt operation. The air compressors, raw water pumps, and revolving cranes operated at 2,200 volts. Conveyors, mixing plant, and other related equipment were operated at 440 volts. Both 2,200 volts and 440 volts were used for cofferdam dewatering pumps.

The camp distribution system consisted of one 2,200-volt, 3-phase primary circuit. Standard single-phase distribution type transformers were provided to step down the voltage from 2,200 to 110/220 volts. Each transformer installation included a set of fusible cutouts and a set of lightning arresters. The total kilovolt-ampere capacity of the distribution transformers was equally divided between the three phases giving essentially a balanced load on the three-phase circuit.

Fire alarm system.—The American District Telegraph Co. was awarded the contract for a complete fire-alarm system. There were several changes made in construction plans after the contract was awarded, and certain adjustments were taken care of through negotiations with the contractor after award.

The system was installed in seven dormitories, mess hall, substation, administration building, hospital, personnel building, and compressor house. With this system the action of initiating the alarm is due to the effect of the fire, wherein the heat given off causes the expansion of air contained in a small copper tube. The tubing was installed upon the ceilings or near the top of the walls. Each end of a loop circuit was connected to a detector unit in such manner that the expansion of the air in the tubing caused a diaphragm within the detector unit to close an electrical circuit which initiated the alarm. The automatic actuation of the alarm was due to the rate of temperature rise.

Manual alarm stations were installed at each of the following locations: trailer camp, time office, field engineers' office, carpenter shop, machine shop, and warehouse. Three buildings, the machine shop, the carpenter shop, and the warehouse, were equipped with sprinkler systems with incorporated automatic devices that would indicate the flow of water into the sprinkler system. The complete fire alarm system was terminated at an annunciator panel located in the fire headquarters. An alarm initiated from any one of the buildings was indicated, as to its location, on the annunciator panel.

The entire fire alarm system was supervised to protect the circuit against abnormal conditions such as interruption or failure of power, and open, short circuited, or grounded circuits.

Power requirements.—The total power consumed for the construction of Douglas Dam from February 1942, through March 1943, was 30,258,800 kilowatt-hours. The maximum 30-minute demand recorded was 6,152 kilowatts, which occurred in November 1942.

MAIN QUARRY AND AGGREGATE PLANT

Main quarry, crushing and sizing plant

Rock for concrete aggregates and sand was obtained from two quarries spaced about 800 feet apart and located on the north bank of the

river, approximately three-fourths of a mile from the dam. Quarry operations and the processing of crushed stone and manufactured sand was contracted to the Birmingham Slag Co. of Alabama. The contract called for approximately 300,000 net tons of manufactured sand at $1.15 per ton and approximately 700,000 net tons of aggregates at $1 per ton to be delivered to the TVA's reclaiming tunnel at a rate to meet the demands of the construction schedule. Quantities were subject to 30 percent increase or decrease without change in unit prices.

Because of war conditions it was necessary for the Birmingham Slag Co. to obtain priorities for the purchase of supplemental equipment. However, great difficulty was experienced by them in obtaining the required priorities, in spite of the efforts by the TVA to expedite the matter. The equipment had been ordered and most of it was ready for delivery. To avoid further delay and to prevent the loss of some of this equipment to others holding high priority ratings, the TVA decided to purchase it on their own priority and allow the Birmingham Slag Co. to use it on a rental basis for the life of their aggregate contract on the Douglas project. The equipment thus purchased from nine manufacturers cost a total of $89,436.17.

The Birmingham Slag Co. found that an additional crusher would be necessary to meet the sand requirements during the peak concreting months of July and August 1942. They requested that the TVA rent to them a Symons 4-foot short head cone crusher located at Fontana Dam, and this was agreed to for a 2-month period at a rental of $500 per month. The contractor had the crusher hauled from Fontana at his own expense on June 26, 1942. The motor was shipped direct to Douglas by the Allis-Chalmers Manufacturing Co. and arrived June 30, 1942. Postponement of the peak concreting period due to foundation difficulties and delay caused by clay seams in the quarry made it necessary to extend the rental period several times. The crusher was finally returned to Fontana Dam on January 31, 1943, at the contractor's expense.

TABLE 16.—*Cost of quarry operation*

Item	Quarry No. 1 north side [1]	Quarry No. 2 south side [2]
Production, cubic yards	103,527	73,374
	Cost per cubic yard	
Operation:		
Preliminary expense	$0.031	$0.045
Drilling	.317	.900
Blasting	.059	.154
Loading and hauling	.101	.311
Quarry service operation	.021	.003
Total quarry operation	.529	1.413

[1] Main quarry.
[2] Quarry for saddle dam riprap.

TABLE 17.—*Cost of concrete aggregate*

Item	Cost per ton
Sand, first cost f.o.b. stock pile:	
[illegible]	$1.153
[illegible]	.005
[illegible]	.016
Total sand used, 313,944 tons	1.174
Handling at stock pile:	
Miscellaneous expense and electricity furnished contractor	.024
Total sand cost f.o.b. stock pile	1.198
Stone, first cost f.o.b. stock pile:	
Stone purchased, 716,968 tons (contract price)	1.000
Land cost and exploratory drilling prorated	.005
Unrecoverable, 23,193 tons	.033
Total stone used, 693,775 tons	1.038
Handling at stock pile:	
Miscellaneous expense and electricity furnished contractor	.024
[illegible] pile	1.062
[illegible] 1,007,719 tons	1.105

Reclaiming tunnel

The crushed stone and manufactured sand were stacked by the aggregate contractor over a reclaiming tunnel built by the TVA (see fig. 59). The tunnel was located, as shown in figure 45, close to hill to permit the contractor to use stackers for conveying the material from his screening structures to the stock pile. Aggregates and sand were stored above the tunnel in five piles and in the following sequence, beginning from the end nearest the quarry: cobbles, coarse rock, medium rock, fine rock, and sand. The piles were spaced 100 feet on centers except the piles containing fine rock and sand where the spacing was 115 feet. With this spacing and approximately 50-foot-high piles a storage of 50,000 tons of aggregates and sand could be obtained.

FIGURE 59.—*Aggregate reclaiming tunnel under construction.*

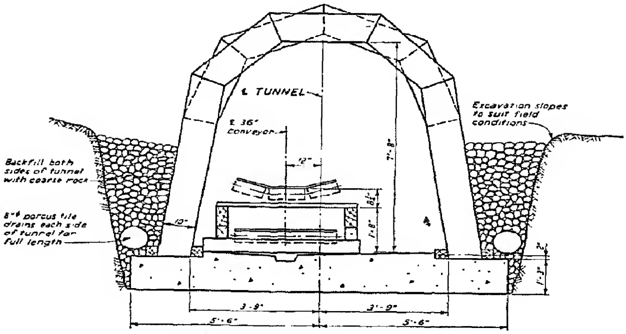
The material was reclaimed by gravity through 16 openings in the tunnel roof and fed by radial-gate-controlled chutes to the first of the five belt conveyors, which carried it to the concrete mixing plant. The openings in the tunnel were so spaced under each pile that material from adjacent piles would not be drawn at the same time and cause a mixture of sizes. There were four belt loading points, 20 feet on centers, for cobbles; six, 16 feet on centers, for sand; and two, 20 feet on centers, for each of the other sizes of aggregates.

The tunnel was 565 feet long and open at both ends. It was built on a ½-percent slope to permit water to drain to a sump pump at the quarry end. The tunnel was built in a 6.5-foot deep trench which, after the tunnel had been completed, was backfilled with coarse rock to help drain water away from the tunnel sides. As a further precaution one 8-inch-diameter porous tile drain was laid on each side of the tunnel for the full length.

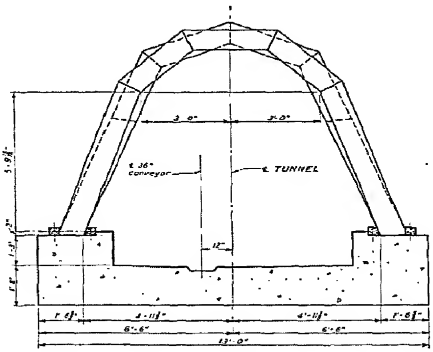
The same design and details used for part of the reclaiming tunnel at Cherokee Dam fitted conditions at Douglas Dam and was therefore used. A cross section of the tunnel is shown in figure 60a. Beginning at the northeast end of the tunnel this section was used for a distance of 513 feet; then for the next 20 feet the tunnel was widened and the floor slab dropped as shown in figure 60b to allow sufficient space for the belt conveyor tail pulley; and for the last 32 feet, a cross section similar to the first one was adhered to.

The tunnel consisted of a reinforced concrete floor slab and a laminated timber arch structure. The slab was reinforced with 1-inch round bars, bent and hooked, and spaced 5½ inches on centers, except that 1-inch square bars spaced 5 inches on centers were required for the widened section of the tunnel. To take care of drainage the top of the slab sloped from each wall to a gutter located on the center line of the belt conveyor. The top of the slab was recessed 2 inches under the walls as shown in figure 60a. Concrete was specified to have a minimum ultimate compressive strength of 3,000 pounds per square inch at 28-day test. A total of 323 cubic yards of concrete and 58,000 pounds of reinforcing steel was required.

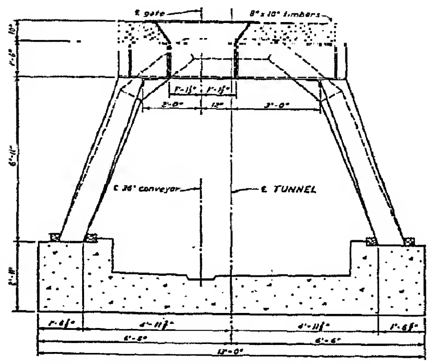
The laminated timber arch structure was built with 4- by 10-inch timber. All pieces were prefabricated in the carpenter shop to exact length and bevels called for in the details to insure full bearing at each joint. The 4-inch thick planks were joined in the field with 5/16-inch diameter by 7-inch long spikes with flat heads and diamond points. The holes for these spikes were ¼-inch diameter. This was done in the carpenter shop when the pieces were fabricated. About 85,000 spikes were required. All timber was specified to be shortleaf southern yellow pine, dense structural square edge and sound, and to be rough. About 210,000 feet board measure of timber was required. At each belt loading point, the arched tunnel roof was omitted and in its stead a steel gate frame was placed to span between the tunnel walls as shown in figure 60c. These gate frames were fabricated from 18-inch channels, weighing 42.7 pounds per foot. Each frame was covered with 10-inch deep timbers except at the opening. The openings were 26 inches wide and 32 inches long in the frames for cobbles and 24.5 inches wide and 31 inches long for all others. The gates consisted of a fixed chute bolted to the bottom of the gate frame, a coun-



(*a*)* *Standard cross section.*



(*b*) *Cross section at tail end of conveyor.*



(*c*) *Cross section showing gate frame.*

FIGURE 60.—*Cross sections of aggregate reclaiming tunnel.*

terweighted hinged chute, and a radial gate to control the flow. Both the latter parts were attached to the fixed chute and were operated manually.

The gates were centered over the belt conveyor which was offset 12 inches from the center line of the tunnel. They were made of ¼- and ⅜-inch thick wear-resisting steel plate. The opening in each frame was lined with ½-inch thick wear-resisting steel plate. Provision was made for inserting a blank plate between the gate and the frame should it become necessary to stop the flow of material in order to repair the gates. Poke holes were also provided to break up any choking of material.

Seven new gates, four for cobbles and three for other sizes of aggregates, and two new gate frames were purchased for $2,289 from the Wisconsin Bridge & Iron Co. The rest of the gates and frames were transferred from Cherokee Dam.

A narrow walkway extended along the riverside of the tunnel. Lighting was provided by 100-watt lamps spaced approximately 20 feet on centers. They were of the ceiling-type outlet, Crouse Hinds Vaportight No. VC–2289. Green signal lamps controlled from selector switches in the head house of the mixing plant signaled the reclaiming tunnel operator which size aggregate was required.

Excavation for the tunnel was done with 1½-cubic-yard Northwest draglines and a bulldozer. The excavated material was used to form part of the protective dike around the stock pile. Concrete for the tunnel floor slab was mixed and placed with a portable mixer. Timber was erected with hand labor.

Belt conveyors

The conveyor system which carried the aggregates and the sand from the stock pile to the concrete mixing plant consisted of five 36-inch belt conveyors, designed to handle 500 tons per hour. Material was fed to and carried by conveyor DG–1 (which was located in the tunnel and extended out under the north access road) to a transfer point (see fig. 61), from which it was then transported by conveyor DG–2 to the rinsing screen where the aggregates were washed; sand was always bypassed and aggregates could be if desired. The conveyors between the rinsing screen and the mixing plant were located on the hillside above the road to the cement unloading point (see figs. 61 and 62). From the tail pulley on conveyor DG–1 to the head pulley on conveyor DG–5 the over-all horizontal length, measured along the center line, was 2661.72 feet and the differential rise was 172.38 feet. The lowest point on the belt system, at elevation 880.75, was the downstream end of conveyor DG–1, and the highest point, at elevation 1051.93, was the discharge end at the top of the mixing plant.

The belt conveyors were started in sequence from the head end and interlocked to prevent a conveyor from discharging material onto a conveyor that was at a standstill. If for any reason the leading conveyor stopped, the conveyor feeding material to it would automatically stop. This type of interlock system has a further advantage in that the operator can immediately locate a conveyor that shuts down because of mechanical or electrical failure.

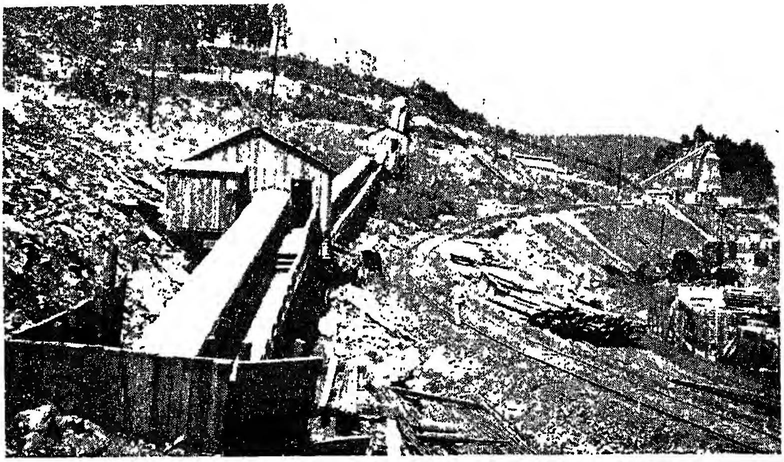


FIGURE 61.—*Belt conveyors DG–1, DG–2, and DG–3.*

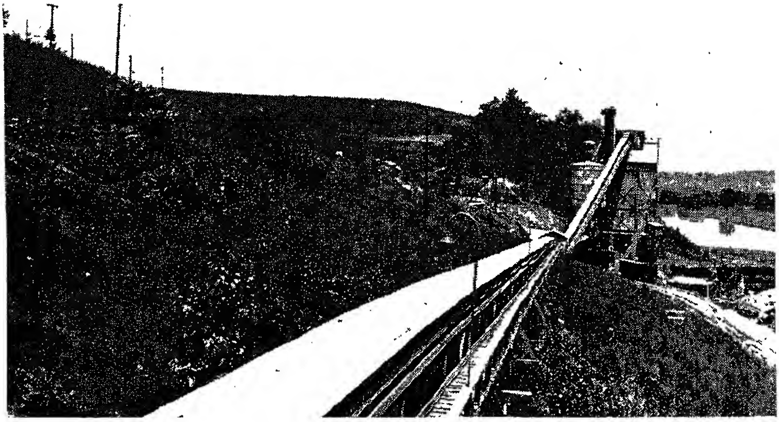


FIGURE 62.—*Belt conveyors DG–4 and DG–5.*

Conveyor DG–1 was powered by a 75-horsepower, 2,200-volt, 3-phase, wound rotor motor, controlled by a full automatic magnetic starter; conveyor DG–2 was powered by a 60-horsepower, 440-volt, 3-phase, squirrel-cage gear motor, controlled by a combination magnetic switch; conveyor DG–3 was driven by a 100-horsepower, 2,200-volt, 3-phase, wound rotor motor, controlled by a full automatic magnetic starter; conveyor DG–4 was driven by a 30-horsepower, 440-volt, 3-phase, squirrel-cage gear motor, controlled by a combination magnetic switch; and conveyor DG–5 was driven by a 100-horsepower, 2,200-volt, 3-phase, wound rotor gear motor, controlled by a full automatic magnetic starter.

The following general data apply to the belt conveyors:

Item	Belt conveyor				
	DG-1	DG-2	DG-3	DG-4	DG-5
Length, horizontal, in feet	840.3	392.7	390.0	791.7	269.7.
Rise, in feet	45.9	38.1	80.2		86.8.
Drop, in feet				32.73	
Belt, 36 inches wide	6- by 8-ply, 42 ounces.	5- by 7-ply, 32 ounces and 28 ounces.	5- by 7-ply, 32 ounces.	4- by 6-ply, 28 ounces.	6- by 8-ply, 36 ounces.
Speed, in feet per minute	226	500	500	500	500.
Motor horsepower	75	60	100	30	100.
Motor output speed, revolutions per minute	1,165	174	1,170	114	47.95.
Reducer ratio	15.49 to 1		5.86 to 1		
Chain drive ratio	70 to 19	54 to 20	53 to 17	16 to 29	No chain drive.
Chain, pitch in inches	2	1¾	2	1½	
Chain, number of strands	3	2	2	2	
Type of automatic take-up	Vertical	Horizontal	Horizontal	Horizontal	Horizontal.

All parts for belt conveyors DG–1 and DG–3 were purchased new. The drive machinery complete with electrical controls were purchased from the Link-Belt Co. The contract with this company also included a sprocket for conveyor DG–4. The total cost of this equipment was $5,957.55. Revolving brushes with 7½-inch diameter spiral rubber rolls were purchased from the Robins Conveying Belt Co. for $925. Each brush had a speed of 375 revolutions per minute and was driven by a 1½-horsepower, 440-volt, 3-phase motor. Pulleys, idlers, holdbacks, and take-ups were bought from the Webster Manufacturing Co., Inc., for $12,079.88. All belting for conveyors DG–1 and DG–3, and a short piece for conveyor DG–2 were furnished by the Boston Woven Hose & Rubber Co. for $14,962.67. The belting was "Bull Dog" brand having a friction of 20 to 24 pounds per inch and a rubber tensile strength of 3,500 to 4,000 pounds per square inch.

The three belt conveyors which were used at Cherokee Dam were transferred and used as conveyors DG–2, DG–4, and DG–5. No new parts were required except 160 feet of additional belting for conveyor DG–2 and a driven sprocket for conveyor DG–4.

Troughing idlers were spaced 3.5 feet on centers except at the loading points where the spacing was reduced to 2 feet. Return idlers were spaced 10 feet on centers. All conveyors were roofed over. Lighting was provided along all the walkways.

To provide passage for the belt conveyor under the north access road, a timber tunnel was constructed before the road fill was made. The inside dimensions of the approximately 200-foot-long tunnel were 6 feet 8 inches in height and 7 feet 2 inches in width. The walls consisted of 8-inch minimum diameter logs; the roof and the bottom were constructed of 10- by 10-inch timber, 10 feet long, with 2- by 4-inch spreaders, laid flat and nailed to the 10- by 10-inch timbers. Drainage along the sides of the tunnel was provided by backfilling with crushed stone next to the walls and by 6-inch open joint tile drains, one on each side.

The conveyors were supported on timber structures with the following exceptions. Most of the conveyor DG–5 was carried on three deck type steel truss spans supported partly by steel bents as shown in figure

100, and where conveyor DG–3 crossed the road to the mixing plant it was supported by a 50-foot-long steel span consisting of three 18-inch-wide-flange beams weighing 50 pounds per foot. The truss spans and the beam span were transferred from Cherokee Dam. No alterations were required to the trusses; they were erected on the same slope, 3⅞ in 12, and the upper span was supported on the mixing plant in the same manner as at Cherokee Dam. The three bents required some alterations. They all had to be cut down in height; and to provide clearances for the railroad tracks two of the bents were supported on 36-inch girder beams, spanning the tracks and supported on concrete columns.

The timber supports consisted principally of 4- by 8-inch stringers to carry the idlers and of 3- by 8-inch stringers to support the 3-foot-wide walkway. The stringers were supported on bents or low frames, spaced approximately 14 feet on centers. In the tunnel, the top of the idler stringers was 1 foot and 8 inches above the tunnel floor, elsewhere 2 feet and 4 inches above the timber walkway, which extended on the right-hand side of the conveyors.

All timber sections, including transfer structures and supports for the rinsing screen, were built with hand labor. A Northwest crane was used to erect the steel beam overpass for conveyor DG–3 and the two lower spans for conveyor DG–5. The upper span was handled with the Clyde gantry crane first put in service.

Rinsing screen

The rinsing screen was an Allis-Chalmers model 1048, triple-deck, low-head screen, 5.5 feet wide and 12 feet long, driven by a 20-horsepower, 440-volt, 3-phase, squirrel-cage motor controlled by a combination magnetic switch. Only the upper and the lower screens were installed. It was transferred from Cherokee Dam and with only minor changes installed at Douglas Dam; a Northwest crane was used to handle and install the screen.

The details of the timber supports, except for the lower part, were identical to the ones used at Cherokee Dam.

TABLE 18.—*Cost of aggregate handling—Storage to mixer*

[984,123 tons]

	Cost per ton
Labor	$0.053
Repairs	.009
Depreciation:	
Aggregate conveyors and screens	.083
Reclaiming tunnel	.056
Miscellaneous expense: air, water, equipment, etc	.034
Total cost	.235

CEMENT HANDLING AND STORAGE

Cement handling and storage equipment was transferred practically intact from the Cherokee project, and installed with minor modifications. Where justified from an engineering and economic standpoint, such a procedure is in accord with TVA practice of utilizing available facilities. Furthermore, in view of the rapid construction schedule arising from the exigencies of a war period, any possible transfer materially helped the purchasing and delivery situation.

In general, the arrangement for unloading and storing cement was substantially the same as the one used at Cherokee, except that the entire plant was located much closer to the dam and concreting operations (see fig 100).

Bulk cement was furnished by three different mills authorized by contract, all located within a radius of 150 miles. Cement was transported by rail to the job. Standard railroad boxcars were lined to prevent cement loss in transit, and each carload was tested and sealed by the inspector before shipment. The total cement delivered to the job was approximately 628,970 barrels.

The unloading shed was designed to accommodate tracks 18 feet on centers so that two boxcars could be unloaded at the same time. Power scrapers unloaded the material into hoppers located between the tracks. In the process the cement passed through vibrating screens and was taken away by chain flight conveyors to bucket elevators. From the top of these elevators the cement was discharged either into a 6,000-barrel silo for storage, or into the cement compartment of the mixing plant, as required. Provision was also made for the cement to flow by gravity from the silo back to the elevators. Except for the silo, all other equipment was furnished in duplicate. Although the peak capacity of the cement handling equipment was about 500 barrels per hour, the maximum yardage for placing concrete probably never exceeded 270 cubic yards per hour requiring approximately 290 barrels of cement. The average demand was more in the order of 240 cubic yards per hour or less, which could be taken care of in case of temporary repairs to one set of equipment.

Cement power scrapers

By the time this equipment was needed for the Douglas project, one of the power shovels, together with supporting frame, screen, and hoppers, had been shipped from Cherokee to another project. Consequently, an identical power scraper was purchased for Douglas from the Webster Manufacturing Co. Each shovel was a right- and left-hand drive double scoop, automatic type unit, complete with scoops, cable, chains, and sheaves, driven by a 10-horsepower squirrel cage induction motor operating at 1,800 revolutions per minute, 220/440 volts, 3 phase, and 60 cycles. The approximate weight of these two units was 2,840 pounds, and they were supported on steel structures at 42 feet on centers.

Cement screens

Screening was necessary to remove lump cement and foreign matter which very often resulted in damage to the cement batcher screw feed.

Consisting of piano wire mesh with ⅛-inch openings, the screens measured about 4 by 7 feet and were so designed as to operate on a 5° downward angle. They had a combined capacity of 750 barrels of cement per hour.

Chain flight conveyors

Two Mass-Flo conveyors were used, each having a capacity of 250 barrels per hour, and each driven by a 15-horsepower, 13-revolution-per-minute gear motor with a resulting conveyor speed of 26½ feet per minute. Both conveyors were furnished by the Jeffrey Manufacturing Co. for the Cherokee project.

Starting horizontally under the tracks, the conveyors were inclined on an angle of 37° and discharged into a feed chute attached to the bucket elevators. The conveyors consisted of alloy steel chains with a 9-inch pitch and with hinged flights on every other link, enclosed in a steel casing 15 inches wide and 24 inches deep. The top plates of the casing were 3/16 inch thick, removable for inspection at loading and discharge points. Side and bottom plates were both 1/4 inch thick, except that the bottom plate was abrasion-resisting steel. The approximate shipping weight for both conveyors was 32,000 pounds.

The conveyors were located under the tracks in a concrete pit with 4-inch thick walls and bottom slab. On account of rock excavation, the size of the pit was kept down to a minimum. The entire cement unloading facilities were protected by a timber framed shed 34 by 104 feet, covered with corrugated roofing and siding, having a clearance of 17 feet 6 inches from top of rail to the bottom chord of roof trusses.

Bucket elevators

The two bucket elevators were originally furnished by the Jeffrey Manufacturing Co. for Cherokee Dam. Each had a capacity of 250 barrels (1,000 cubic feet) of cement per hour based on an aerated weight of 65 pounds per cubic foot. The elevators were equipped with 24- by 8- by 3/16-inch Century high-back buckets spaced 24 inches on two strands of alloy chain with a 6-inch pitch and were driven by a 15-horsepower, 71-revolution-per-minute gear motor, which gave an elevator speed of 125 revolutions per minute.

Spaced 6 feet on centers, the elevators discharged through a common chute with a fly valve which directed the material by means of 16-inch diameter by 1/4-inch-thick pipes either to the cement silo or mixing plant. Cement was reclaimed by gravity from the silo back to the elevators through a 16-inch diameter pant-leg pipe. By installing two bucket elevators it was possible to continue delivery of cement without interruption in event of repairs to the bucket chains of one elevator.

The approximate shipping weight of both elevators was 73,000 pounds.

Cement silo

The 6,000-barrel-capacity silo was one of the two originally purchased for the Norris project, and this was the fourth transfer. The silo had a diameter of 30 feet, a height of 64 feet 5 inches from the column bases to the top, and was supported on eight 12-inch, 65-pound section, wide-flange columns. The bottom of the silo was conical and to it was attached a 14-inch rotary gate valve leading to a pant-leg consisting of 16-inch-diameter pipes. The flow into either pipe was controled by a butterfly valve. Holes were provided in the bottom of these pipes and in the conical part of the tank for standard 3/4-inch-pipe couplings, for the purpose of aerating the cement, when required, to prevent clogging.

The cement silo was provided with a 7-foot-diameter vent, 9 feet high, mounted on the top. Actual loss of cement varied from 0.1 to 1.0 percent. To suit the particular layout requirements the silo had to be elevated on a concrete supporting structure. Eight reinforced concrete columns, 32 inches square, were used to provide an additional height of 18 feet. Because of the rock foundations, isolated footings 5 feet square and 3 feet deep were used, as compared

with a ring-shaped slab for Cherokee Dam. An allowable rock pressure of 20,000 pounds per square foot for the combined dead and live loads was adopted.

The columns were tied at the top with struts 12 inches wide and 18 inches deep. Approximately 60 cubic yards of concrete and 6,000 pounds of reinforcing steel were required for the supporting structure.

Concrete was supplied for the footings by a portable mixer and placed from timber ramps while a 1-cubic-yard bucket handled by a Northwest crane placed concrete in the columns. The same crane was later used for erecting the steel columns, and the remaining parts of the silo were erected by the 40-ton Clyde crane from an adjacent track.

TABLE 19.—*Cement costs*

[614,030 barrels]

	Cost per barrel
Operating labor	\$0.052
Job railroad system	.196
Miscellaneous supplies and expense	.003
Repairs	.019
Total operation	.270
Cement f.o.b. Sevierville, including testing	2.111
Plant depreciation	.079
Total cost cement delivered to mixer	2.460

CONCRETE MIXING PLANTS

Main mixing plant

The concrete mixing plant was transferred from Cherokee Dam. The general arrangement was practically the same at Douglas Dam as at Cherokee Dam (see fig. 45). Only minor revisions were required. Instead of the center of the mixing plant being located on the line through the centers of the cement silo and the bucket elevators, it was offset approximately 6 feet from that line; this necessitated minor changes in the chutes going from the top of the bucket elevators to the cement silo and to the cement compartment in the mixing plant. Because the trains entered the mixing plant from a different direction the lower cross-bracing in two of the bays had to be relocated. At Cherokee Dam it had been necessary to spot the concrete bucket under the wet-batch hopper before the mixer could be dumped. To avoid this handicap at Douglas Dam a radial gate was installed at the bottom of the hopper.

The footings for the mixing plant were 6 feet square and 3 feet deep. The reinforced concrete mixer platform was identical in design to the one used at Cherokee Dam, except that the footings for the columns were 3 feet square and at least 3 feet deep. All footings were extended to sound rock, and each was anchored by eight 1-inch-diameter dowels. The maximum bearing pressure was 10 tons per square foot. Concrete was specified to have an ultimate compressive strength of not less than 2,500 pounds at a 28-day test.

Concrete for the footings and the mixer platform was supplied by transit-mix trucks. Concrete for the footings was poured directly from the trucks into the forms. Congrete for the platform and its

supporting columns was placed with 1-cubic-yard buckets handled with a Northwest crane.

TABLE 20.—*Concrete mixing plant costs*

[544,083 cubic yards]

	Cost per cubic yard
Operating labor	$0.138
Power, water and air	.066
Miscellaneous materials and expense	.017
Repairs	.028
Plant depreciation	.226
Total cost	.475

Auxiliary batching plant and portable mixers

For placing small amounts of concrete in places inaccessible to the gantry cranes operating on the construction bridge an auxiliary batching plant serving transit-mix trucks was constructed. The batching plant consisted of a Blaw-Knox, 105-ton, three-compartment bin complete with one 2-cubic-yard batcher and cement loading chute. It was rented from Wilson-Weesner-Wilkinson Co. for $250 per month and later purchased for $3,000 less accrued rental. The location was approximately 300 feet downstream from the main concrete mixing plant. A timber ramp supported on trestle bents extended from the road back of the bin to the top of the bin to provide for filling by trucks (see fig. 63).

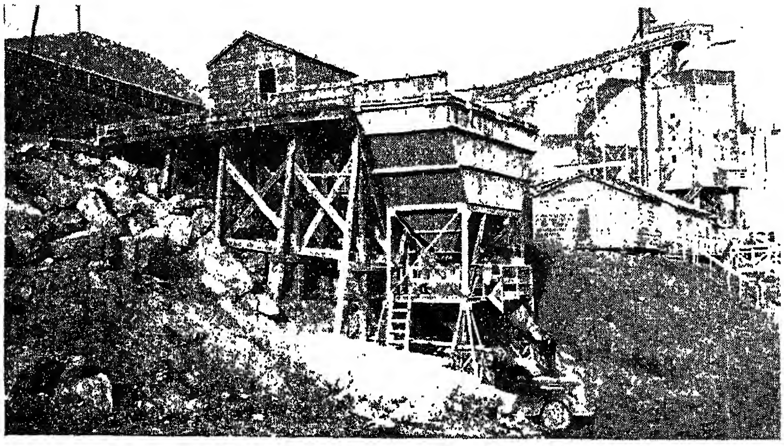


FIGURE 63.—*Auxiliary batching plant.*

Five transit-mix trucks with 1½-cubic-yarld mixers were purchased for use with the auxiliary batching plant, though the maximum number in use at any one time was only three, two being transferred to other jobs. Three of these were rented from the Birmingham Slag Co. for $300 per month each and later purchased for $3,500 each, less accrued rental. Two more were purchased from the same company for $3,500 each.

In addition to the above, three portable ½-cubic-yard mixers were used for small pours. Transit-mix trucks supplied the concrete for the main mixing plant footings and the mixer foundations, and also for the lower end of the tailrace wall, portions of the apron weir wall, and the core wall for the north abutment. Other items of concreting done by transit-mix trucks or portable mixers were switchyard footings, curbs, manholes, powerhouse floor finishes, etc. Concrete for the cement silo footings was supplied by one of the portable mixers.

CONCRETE HANDLING AND PLACING

Concrete was discharged from the three mixers into a conical shaped steel wet batch hopper, which had a capacity of 25 cubic yards. From the hopper the concrete was loaded into buckets through an air-operated radial gate. The buckets were hauled by trains to any one of four 40-ton capacity electric gantry cranes, which, operating on the construction bridge, placed the concrete in the forms. The concrete in blocks 1, 2, and 3, which were out of reach of the gantry cranes, was placed with a stiffleg derrick. Part of the spillway apron and training walls was also out of reach of the gantry cranes. Concrete for these parts of the dam was hauled from the mixing plant on a flatcar equipped with three 4-cubic-yard hoppers. This concrete was discharged over the downstream side of the construction bridge, through an elephant trunk, into a hopper at the base of the dam. From the hopper, concrete was loaded into 2-cubic-yard buckets and hauled by truck to crawler cranes, for placing in the aforementioned places.

Concrete haulage

Concrete was hauled from the mixing plant by trains, each consisting of a locomotive and one flatcar. Six 40-ton flatcars, 32 feet long, were transferred from Cherokee Dam. These were factory rebuilt cars purchased for Cherokee Dam at a cost of $1,106.90 each. These cars were equipped by TVA with operating platforms and bucket guides to facilitate spotting the buckets (see fig. 64). Three loaded buckets were carried on a car and there was additional space for setting one empty bucket.

Five standard-gage locomotives were purchased new. These included three General Electric 25-ton Diesel-electric locomotives purchased at $13,180 each and two Plymouth 18-ton gasoline locomotives purchased at $9,400 each. The 25-ton General Electric locomotives had a 72-inch wheelbase and an operating weight of 49,000 pounds. They operated, forward or reverse, at speeds of 1½ miles per hour to 20 miles per hour with tractive effort varying from 15,000 pounds at 1½ miles per hour to 1,200 pounds at 20 miles per hour. The 18-ton Plymouth locomotives had a 63-inch wheelbase and an operating weight of 36,000 pounds. They operated in four speeds, forward and reverse, with tractive effort varying from 9,000 pounds at 2½ miles per hour to 3,260 pounds at 13½ miles per hour.

The concrete transfer tracks were located as shown in figure 100. The length of track from the mixing plant to the extreme south end was about 1,300 feet. Eighty-five-pound ASCE rails and No. 6 frogs were used. The maximum degree of curvature was 30°.

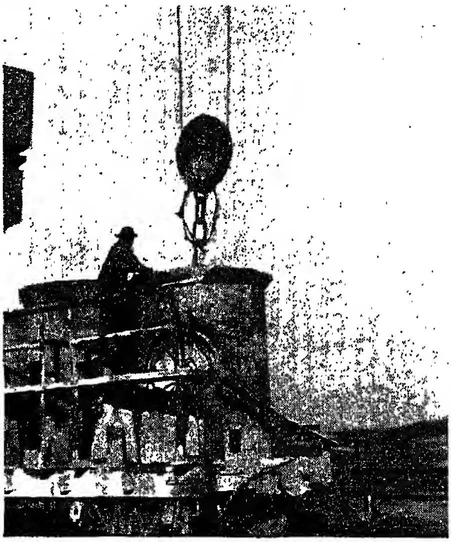


FIGURE 64.—*Flatcar with concrete buckets.*

TABLE 21.—*Concrete haulage costs*

[535,512 cubic yards]

	Cost per cubic yard
Operating labor	$0.077
Equipment (locomotives, 13,510 hours)	.082
Miscellaneous material and expense	.010
Repairs	.032
Depreciation:	
Buckets, trucks, cars, hoppers, etc	.045
Construction trestle	1.247
Total cost	1.493

Construction bridge

Six additional deck spans were required in addition to the spans which were transferred from Cherokee Dam. They were made identical with existing spans, so that no new detail drawings were required for their fabrication. Only about one-third of the steel required for all-steel towers was available from Cherokee Dam. In order to avoid possible delay in construction due to failure of steel deliveries, and to conserve structural steel, which was then a critical war material, two of the towers and the lower parts of the others were built of reinforced concrete (see figs. 65 and 66). The cost of these concrete towers was high. Some existing tower steel was shipped to the fabricator for alterations, and a small amount of new tower steel was purchased.

Figure 67 shows the typical section of the construction bridge. From station 6+57 to station 17+52 the bridge paralleled the dam, with the center line of the gantry track at a distance of 93 feet 9 inches from the axis of the dam. The bridge towers and spans were arranged as shown to clear the penstocks (see fig. 65) and sluiceways.

The curve at the north end was necessary to bring the concrete track under the mixing plant. At the south end, the steel deck ended at station 17+52.06 and beyond this point the gantry rails were carried on concrete walls and pads, while the concrete tracks were supported on a timber structure. The curve at the south end was necessary to

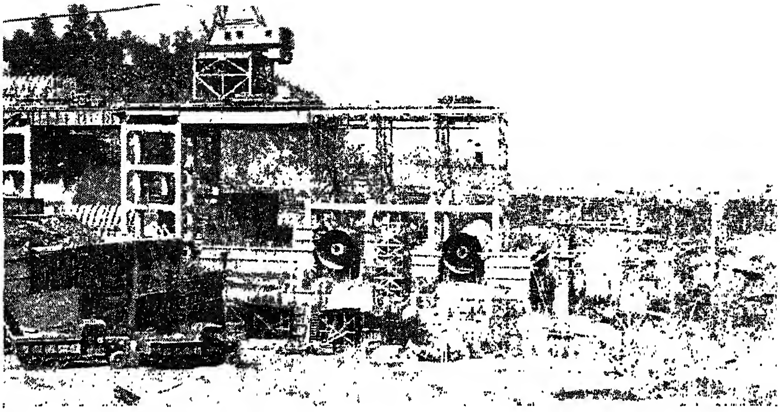


FIGURE 65.—*North end of construction bridge. Note towers clearing penstocks. The two towers at left are of reinforced concrete for the full height, the others are part concrete and part structural steel.*

FIGRUE 66.—*Construction bridge during erection. Note diversion channel in foreground.*

keep the upstream gantry rail outside the dam excavation (see fig. 68). The total length of the gantry track was about 1,330 feet.

Steel structure.—The bridge deck was of steel framing with the gantry rails supported directly on the main girder spaced 30 feet on centers. Two concrete tracks, 12 feet on centers, were located be-

tween the gantry rails. Between stations 8+14 and 15+02 a third line of girders 29 feet 6 inches downstream from the center line of the gantry track, supported framing for a narrow walkway and a

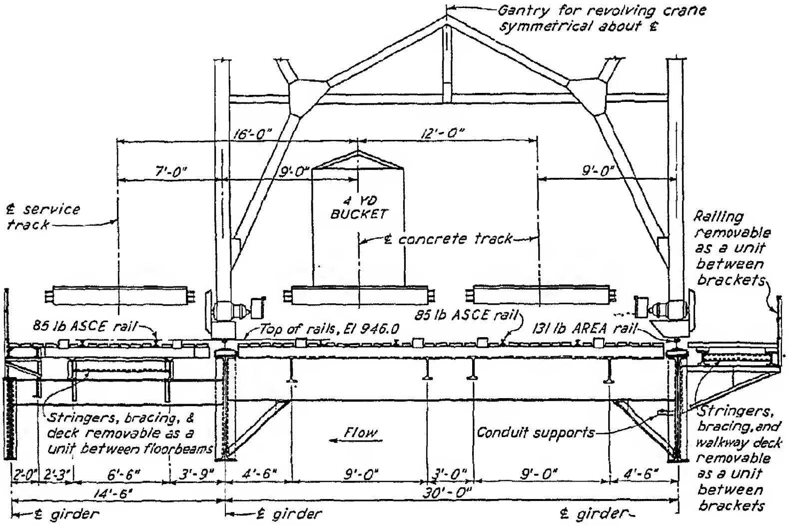


FIGURE 67.—*Typical section of construction bridge.*

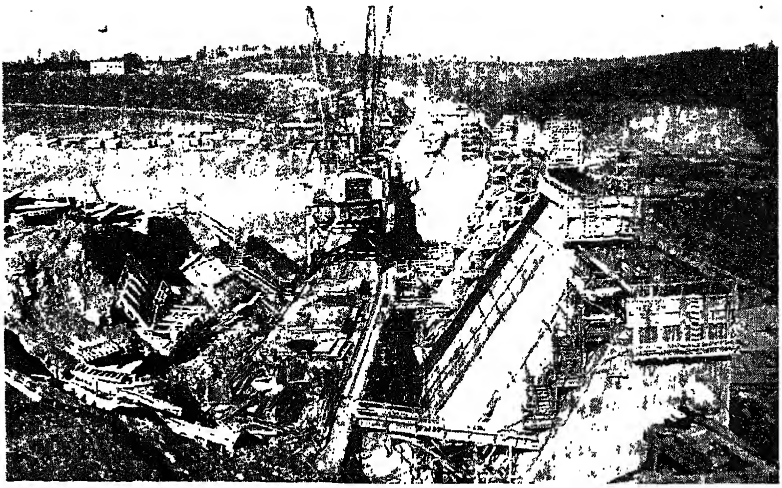


FIGURE 68.—*Gantry track extension, south bank.*

general service track. An access walkway, 6 feet 6½ inches wide, was carried on brackets cantilevered from the upstream girder.

The concrete tracks were supported on 8- by 8-inch timber ties, 14 feet and 2 inches long. Rails, ties, 8- by 8-inch guard timbers, and

3-inch planking were joined together to form panels, between floor beams, that could be removed when concreting below the bridge. Similar removable panels were used in the service track area, but here it was necessary to include the steel stringers as part of the panels to permit lowering the concrete buckets through the deck. For the service track 8- by 10-inch ties, 11 feet and 6 inches long, were used. The construction bridge at Cherokee Dam was designed for the following design loads:

Live loads:

Concrete tracks, one 10-ton locomotive and one 50-ton capacity car; or one 10-ton locomotive and two cars each loaded with three 4-cubic-yard buckets, weighing 22,000 pounds each.

Service track, one 10-ton locomotive and one car. Maximum weight of load and car, 125 tons.

Crane track, one crane, or two cranes on 60-foot centers. Each crane with a live load of 22,000 pounds plus 50 percent impact at 135-foot radius; or two cranes on 60-foot centers with a single live load of 44,000 pounds plus 50 percent impact at 135-foot radius (no slewing forces were considered with this loading).

Maximum moment caused by slewing, 660,000 foot pounds.

For crane track between towers 7 and 10 (at powerhouse), two cranes on 37-foot centers with a single live load of 160,000 pounds at 45-foot radius (no impact).

Walkways, 100 pounds per square foot.

Snow load: 10 pounds per square foot.

Wind load: 25 pounds per square foot on vertical area of structure and cranes with cranes not operating, or 8 pounds per square foot with cranes operating.

The loading conditions at Douglas Dam were the same as for Cherokee Dam, with the exception that locomotives weighing up to 25 tons were used for hauling concrete trains.

The sizes of main members are given in table 22.

TABLE 22.—*Sizes of main members, construction bridge*

Item	63- and 68-foot spans	30- and 30-foot 6-inch spans
Crane girders:		
Depth (back to back flange angles)	8 feet ½ inch	4 feet ½ inch.
Section modulus (in. 3):		
Upstream girders	3600 (63-foot span) 4230 (68-foot span)	1330.
Downstream girders	4230 (63-foot span) 4920 (68-foot span)	1540.
Service track girders:		
Depth (back to back flange angles)	6 feet ½ inch	30WF116.
Section modulus (in. 3)	1100	
Floor beams:		
Between crane girders	1-36WF160 (fixed end) 2-36WF170 (interior) 1-36WF150 (expansion end)	1-36WF150 (interior). 1-33WF132 (expansion end). 1-33WF132 (expansion end).
For service track arrangement	24WF74 3 bays at 21 or 23 feet	24WF74. 2 bays at 15 feet ±.
Stringers:		
For concrete tracks	21WF59 (inside) 21WF63 (outside 63-foot span). 21WF68 (outside 68-foot span).	16WF40 (inside). 16WF (outside).
For service track	24WF74 (63-foot spans) 24WF80 (68-foot spans)	18WF55.

Item	All towers
Tower columns:	
Upstream	14WF119.
Center	14WF136.
Downstream	14WF68.

Towers 1 to 10, inclusive, were partly of steel. The upstream columns varied in height from 14 to 35 feet; the center and downstream columns varied from 25 to 51 feet. To have made the towers entirely of steel would have required an additional 1,280,000 pounds.

TABLE 23.—*Approximate quantities and cost of steel in the construction bridge*

Item	Transferred from Cherokee		New at Douglas	
	Pounds	Cost per pound	Pounds	Cost per pound
Deck steel:				
Rolled sections	744,000	$0.0386	178,000	$0.067
Plate girders	1,180,000	.0441	249,000	.067
Bracing	212,000	.0516	40,000	.067
Tower steel:				
Rolled sections	157,000	.0496	56,000	.067
Bracing	251,000	.0516	146,000	.067
Masonry plates	5,000	.0496	55,000	.042
Total	2,549,000		724,000	

Concrete towers.—The reinforced concrete towers were designed as rigid frames. The columns below the gantry crane girders were all 3 feet and 8 inches square, except the ones for towers 11 and 12 which were 3 feet and 6 inches square. The downstream columns (for the service track) were 3 feet square. All columns were stiffened with struts, spaced approximately 20 feet on centers. The footings under the columns were either 6 or 7 feet square, but the height varied considerably. The footings for tower 8 were built on the dam structure after the concrete in the block at that tower had been placed to elevation 846. All other footings were carried to sound rock. The footings for concrete towers 1 to 12 were mostly within the area of the dam and were built when the dam excavation had been completed at the footing location. The maximum bearing pressure was 20 tons per square foot. Concrete was specified to have a minimum ultimate compressive strength of 2,500 pounds per square foot at 28-day test. A lower bearing pressure and concrete strength was used for the north abutment, piers 13 and 14, and the gantry rail wall at the south end.

Approximately 3,930 cubic yards of concrete and 767,000 pounds of reinforcing steel were required for the towers, the piers, and the abutment.

Erection of the bridge began with the excavation and concreting for the north abutment and piers 13 and 14 in April 1942. The construction of the concrete towers progressed from the north end, as dam excavation advanced from the right bank and over toward the left bank. All concrete towers out to and including tower 3 were built in the first-stage cofferdam. Towers 1 and 2, at the south end, were located in the first-stage diversion channel. They were, however, among the first ones started, and the concrete part of these towers was completed before the water was diverted through the channel.

The erection of steel followed immediately after the concrete structures had been completed. All steel spans and towers, except steel towers 1, 2, and 3, were handled and erected with one of the 40-ton Clyde revolving cranes. Whenever practical, this crane, operating from the completed section of the bridge, would also place concrete for

the concrete towers. Where the concrete towers were out of reach of the crane, concrete was placed by a pumpcrete machine, or by truck-carried 2-cubic-yard buckets handled with a crawler crane.

The deck spans were designed to be erected from south to north, or opposite to the order which had to be followed at Douglas Dam. The long girders were 8 feet deep and were supported directly on the towers. Each girder was fabricated with a seat at the north end (fixed end) on which the south end of the 4-foot deep tower girder rested. The other end of the tower girder was supported on the tower by a 4-foot deep bracket attached to the bottom of the girder. This meant that in order to erect the tower span the following long span and the next tower had to be erected first. This would have caused some delay. To permit erecting the spans on towers 7 to 3, without waiting for the next tower to be completed, temporary brackets were designed similar to those already provided at the north end. They were fabricated in the field and attached to the south end of the girders. Thus, the span on tower 7 could be erected and the deck and track installed without having to wait for span 6–7 to be in place. As soon as span 6–7 had been erected, span 7 was supported in the regular manner, the temporary brackets were removed and attached to the south end of the girders in span 6. These were then erected, as soon as tower 6 had been completed; and then the same procedure, as described for tower span 7 and span 6–7, was followed, until all spans over to and including the span on tower 3 had been erected.

The steel sections of towers 3 and 2 were erected with a Northwest crane operating from the top of the first-stage cofferdam. The steel section of tower 1 was erected by a Lorain crane operating from the top of the rock bluff excavation.

TABLE 24.—*Cost of construction bridge*

Foundations and concrete towers	$383, 823
Timber decking and walkways	47, 190
Structural steel (first cost and erection)	238, 580
Dismantling	43, 417
Total (rails not included)	713, 010

Concrete buckets

The following buckets were used:

Number	Make	Capacity (cubic yards)	Cost new
2	Heltzel	1	$200
12	Dravo	2	550
4	do	3	660
17	do	4	890

The Heltzel buckets and six of the 4-cubic-yard Dravo buckets were purchased new for Douglas. The remainder were transferred from other TVA projects. Most of the concrete in the dam was placed with the 4-cubic-yard buckets, the other being used where quantity of concrete or limited clearance made the use of the large buckets impracticable. The Dravo buckets were operated by handwheels and were suitable for handling close to forms and storing close together on cars, as none of the operating mechanism projected beyond the outside skin plate.

TABLE 25.—*Operating characteristics of electric cranes*

Number and make	2 Clyde	1 American	1 Dravo.
Purchased for	Cherokee	Kentucky	Pickwick.
Cost new, in dollars, each	57,588	52,380	41,930.
Length of boom, in feet	125	125	115.
Capacity, in tons:			
135-foot radius	11	11	
125-foot radius			11.
45-foot radius	40	40	40.
[illegible]	34	34	34.
[illegible]	30	30	30.
[illegible]	31.67	25.58	31.5.
Rail circle diameter, in feet	28	25	29.
Travel speed, in feet per minute	50	50	50.
Main three-drum hoist:			
Horsepower	200	200	200.
Volt	440	440	440.
Phase	3	3	3.
Cycle	60	60	60.
Swinger motor:			
Horsepower	75	75	50.
Volt	440	440	440.
Propel motors (on 2 trucks):			
Horsepower	15	15	10.
Volt	220/440	220/440	440.
Line pull, in pounds:			
For 250 feet per minute	24,000	24,000	24,000.
For 400 feet per minute	14,000	14,000	14,000.
[illegible]ns	50	62	50.
[illegible] cwt, in pounds	380,000	435,000	320,000.
Cranes placed in service at Douglas Dam	Apr. 14, and May 30, 1942.	Nov. 23, 1942	July 25, 1942.

Cranes for placing concrete

Four electric, 40-ton, full revolving gantry cranes were transferred from other TVA projects.

The first crane was erected on a temporary track laid on the mixing plant site. A 1½-cubic-yard Northwest crawler crane was used to erect the gantry base and frame. The rotating platform was placed by the Northwest crane and a 2-cubic-yard Lorain crawler crane working together. Each succeeding crane was erected by the 40-ton gantry cranes.

The bridge circuit for operating the cranes consisted of three 4/0-R. C. 2,400-volt cables in a 3-inch galvanized iron conduit. Steel switch boxes with suspended platforms, under the bridge deck, were provided throughout the length of the bridge, with access through manholes in the deck of the bridge. The switch boxes were located about 200 feet on centers, and each box contained three 2,400-volt fused cut-outs and three disconnecting switches. The portable power cables of the cranes were connected to the 2,400-volt 3-phase line through these switch boxes.

TABLE 26.—*Gantry crane operating costs*

[Three 40-ton cranes, 21,368 hours]

	Cost per hour
Operating labor	$6.152
Power	.542
Miscellaneous supplies and expense	.172
Repairs	.821
Erect and dismantle	2.537
Depreciation	1.017
Total cost	11.241

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*TVA staff member.

CHAPTER 5

CONSTRUCTION

The construction of Douglas Dam started February 2, 1942. Production of power for defense plants in the vicinity was scheduled by TVA to begin in March 1943, and to achieve this goal it was necessary to begin water storage during the winter of 1942–43. The construction of a dam and power plant of this size in 13 months' time, especially under the extremely difficult foundation conditions encountered, required skillful planning, an experienced construction organization, and close coordination of all activities. To place the power unit in commercial operation March 21, 1943, required the placing of 548,200 cubic yards of concrete; 824,500 cubic yards of earth and rock fill, of which 708,200 cubic yards was placed in a dike and eight small saddle dams; and the excavation of 622,700 cubic yards of material, 54 percent of which was rock. In addition, the work involved the assembly and erection of a large construction plant, extensive cofferdam work, and major foundation treatment.

CONSTRUCTION PERSONNEL

Employment procedure

The Tennessee Valley Authority Act[1] specifies that all appointments shall be made on the basis of merit and efficiency without political test or consideration. In staffing the Douglas project, as in all other TVA employment, the spirit and letter of this provision were observed.

Trades and labor personnel.—Practices in recruiting trades and labor personnel were focused on utilizing the services of employees who had gained experience and training on other projects of the TVA, particularly in the skilled groups. When recruitment for Douglas was under way the effects of the wartime labor market were increasingly being felt, and it was necessary to expand and intensify recruitment efforts.

The necessity for an accelerated construction schedule required that a large number of workers be placed on the job immediately following the authorization of the project. An estimated 1,800 employees were working on the project 4 days after authorization by Congress. As of February 28, 1942, there were 2,599 employees on the pay roll; 4,458 by March 31, 1942; and 6,219 by June 30, 1942. The speed and efficiency with which this project was completed indicate that TVA was successful in obtaining qualified personnel despite the difficulties of the labor market.

[1] See Sec. VI, Tennessee Valley Authority Act, Public, No. 17, 73d Cong., as amended by Public, No. 412, 74th Cong.

The critical labor market required utilization of all available sources of manpower. Large numbers of semiskilled Negro employees helped to meet this situation; approximately two-thirds of the Negroes employed were in semiskilled or skilled categories.

Professional, administrative, technical, and clerical personnel.—Personnel in the professional, administrative, technical, and clerical fields of work were appointed without regard to geographical residence. A substantial number were transferred from the Cherokee and other TVA projects; others were selected from applications in the TVA's files. Approximately 50 percent of all persons employed during construction of the project had had previous experience on TVA projects. All employees selected were required to pass a physical examination.

Salary and wage schedule

Before this project was begun, the TVA had adopted its own salary schedule for non-trades-and-labor positions. Salary rates were generally equivalent to the prevailing rates for comparable work in federal service. Job supervisors prepared descriptions of duties for annual-salaried positions, which were currently modified as jobs changed. Positions were classified on the basis of duties and responsibilities, following standards prevailing throughout the TVA organization, with due regard to standards prevailing in the federal service. In this manner comparable salaries were paid for comparable work. Wage rates for trades and labor occupations, both hourly and annual, were established annually in conference with recognized employee organizations and were based on the prevailing rate of wages for similar occupations in the vicinity, as stipulated in the statute creating the TVA. The hourly wage schedules in effect during the construction period are included in appendix D.

Labor relations

The employee relationship policy,[2] adopted in August 1935, provides for the orderly handling, through joint machinery, of matters of mutual interest to management and employees. The general agreement between TVA and the Tennessee Valley Trades and Labor Council [3] signed in August 1940 supplements the provisions of the employee relationship policy and provides for collective bargaining on all matters that affect trades and labor employees.

The employee relationship policy provides that disputes between an employee and management be handled by the employee or his representative through established supervisory channels. Failing prompt and satisfactory adjustments, the employee or his representative may appeal the dispute to the personnel organization for investigation and adjustment.

Under the terms of the general agreement, trades and labor employees may, through their organizations, appeal from a decision of the personnel director to a joint board of adjustment, which in turn may refer the matter to an impartial referee.

In accordance with an agreement reached between the TVA and the Tennessee Valley Trades and Labor Council to establish joint

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[2] Tennessee Valley Authority Technical Report No. 1, *The Norris Project*, 1939, appendix I.
[3] Tennessee Valley Authority Technical Report No. 6, *The Chickamauga Project*, 1942, appendix D.

cooperative labor-management committees on various projects, such a committee was established at Douglas Dam in January 1943 and continued until completion of construction. This committee promoted employee interest in the war significance of the project, war-bond purchases through pay-roll deductions, employee suggestions for increased efficiency, and in better job attendance. The personnel organization supervised the enforcement of labor provisions on work performed by contractors.

Training and educational relations

During the construction of Douglas Dam, most of the employees lived in the nearby communities of Sevierville, Dandridge, Jefferson City, and Morristown. A trailer camp and dormitories were provided at the dam, but no family residences were erected.

The only school children for whom the TVA was responsible were those from the trailer camp. The camp was located in Sevier County; but, since Dandridge, in Jefferson County, was more conveniently located and maintained fully as satisfactory a school program as other nearby communities, children from the camp were sent there under a contractual arrangement with the Jefferson County Board of Education.

The relocation of schools and school bus routes in Jefferson County was a particularly difficult problem. Upon request of the county and state officials, TVA assisted in school surveys and in the formulation of future plans for the school program of the county. School problems in Sevier and Cocke Counties were less serious, but some assistance was given in making necessary adjustments.

Library service was arranged by contract with the Board of Library Trustees of Knoxville and the State Department of Education in cooperation with the local libraries of the affected counties. A camp library and a regional library service were established for employees at the project. This service included technical, recreational, and general educational books and periodicals. Considerable use was also made of 16-millimeter films, handled through the library, for educational and recreational purposes. This program, together with similar ones at Watts Bar and Fort Loudoun projects, was valued so highly by the state that the legislature appropriated $20,000 for continued operation of the regional library service.

Recreation services in the Douglas area were centered in the community building at the construction camp and were supervised by a recreation specialist. Indoor and outdoor sports, games, and other entertainment were organized. The recreation supervisor also cooperated with surrounding communities in organizing recreational programs and assisted them with film services.

Training classes for employees were conducted at the dam and in nearby urban centers. Special emphasis was placed on training in fields where recruitment was difficult. For example, training was provided for public safety officer-trainees, sergeant-trainees, and engineering survey parties.

Labor and management joined in conducting an apprentice-training program for selected young men capable of attaining the craft skill required for journeyman work. In addition, evening extension courses were conducted in industrial safety and hygiene, typing, shorthand, shop sketching and blueprint reading for machinists, training

for vounteer firemen, and maintenance of air tools. Arrangements were also made for apprentice classes in nontechnical subjects. A class in public speaking proved to be popular.

Labor turn-over

The higher labor turn-over at Douglas than at earlier TVA projects reflected the unstable wartime labor market. A prominent factor causing both turn-over and absenteeism was the 7-day-workweek schedule, which caused cumulative fatigue and allowed no time for attending to personal business. Other factors were transportation difficulties, rapid induction of employees into the armed forces, competition within the labor market, and the mobility of labor. Table 27 gives the average monthly labor turn-over for work at the dam and for reservoir clearance. Figure 69 shows the number of employees in each general classification by months.

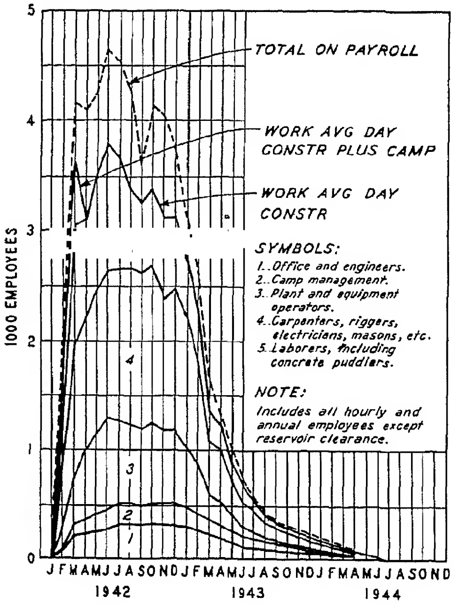


FIGURE 69.—*Monthly employment.*

TABLE 27.—*Average monthly labor turn-over* [1]

Item	Dam construction [2]		Reservoir clearance [3]	
	Number	Percent	Number	Percent
Discharged	67	2.5	17	3.3
Laid off	97	3.6	1	.2
Resigned	251	9.4	106	20.2
Other	41	1.5	9	1.6
Average exits per month	456	17.0	133	25.3
Average number employed	2,677		524	

[1] For the [illegible] activity exceeded 400,
[2] For a 20 [illegible] 943.
[3] For a 12 [illegible]

Medical service

The need for health and safety services was immediate upon the start of construction February 2, 1942.

The initial medical service at Douglas was a mobile first-aid unit. A junior medical aide was placed in charge, and patients needing a physician were transported by ambulance to the hospital at Cherokee Dam. This type of service continued until early spring, 1942, when a first-aid station was constructed at the Douglas project. Early in the summer, the hospital was completed; and personnel and equipment were transferred from the Cherokee project. This hospital had 20 beds, 4 bassinets, operating and delivery room, nurses' supply room, examining room, X-ray and clinical laboratory, first-aid room, 2 doctors' offices, head nurse's office, clerical office, reception hall, kitchen, and staff dining room.

During the peak of employment, the medical service staff consisted of health officer in charge, three associate medical officers, a chief nurse, eight graduate nurses, an assistant clerk, two junior clerks, one cook, one junior cook, nine junior medical aides, and four orderlies. Service in the hospital was rendered on a 24-hour basis. The junior medical aides also gave 24-hour coverage 7 days per week in the two first-aid stations located on the job.

Throughout the construction period, medical service for the reservoir crews was given by the reservoir medical unit in Morristown, Tenn. When major construction was completed, service to the remaining reservoir crews was provided from the hospital at the dam. Personnel of the reservoir medical unit consisted of one associate medical officer, one assistant medical aide, two junior medical aides, and one junior clerk.

The medical-care program for employees and nonemployees and their dependents living within the construction area was made available in June 1942 on a voluntary participation fee basis and continued until the hospital was closed in December 1943. Services offered were those which could be rendered by well-trained general practitioners of medicine provided with usual medical equipment and facilities.

After closure of the hospital, health and safety services were rendered by a doctor, a nurse, and a clerk with offices in the basement of the administration building until April 15, 1944, when all construction work had been completed.

A tabulated summary of medical services rendered during the reservoir and dam construction follows:

Out-patient service:	
Examinations	24, 010
Immunizations	8, 736
Inspections for approval for duty	9, 072
General medical services	35, 221
Surgical procedures	310
Venereal disease treatments	4, 096
Hospital service:	
Surgical procedures	80
General medical services	10, 723
Hospital admissions	332
Hospital days	1, 997
Venereal disease treatments	1, 206
Spinal punctures	29

Laboratory service:	
Urinalysis	7,997
Examinations of blood	8,635
Examinations of smears	206
X-rays	3,210
Home service:	
Professional visits	57

Environmental sanitation

Drinking water for employees working at the dam site was supplied from a nearby spring protected against pollution. The only treatment used for this water was chlorination. A chlorine residual ranging from 0.30 to 1.00 part per million was maintained.

Drinking water for field forces was hauled in tank trucks. Since this water in some cases was obtained from questionable sources, a chlorine residual ranging from 0.3 to 0.5 part per million was maintained at the barrels used by each crew in order to assure a safe water supply. Biweekly checks of the drinking water used by isolated crews showed that it was satisfactory.

The sanitary sewerage system for the project, to which all sanitary fixtures were connected, consisted of 6-inch mains for collection and a septic tank for treatment. With the approval of the State Health Department of Tennessee, the effluent from this tank was discharged raw into the French Broad River.

The TVA operated a large cafeteria in the construction area. Weekly inspections were made to determine the quality of the food and handling conditions. Rigid sanitary regulations were met satisfactorily.

Safety service

Construction of the Douglas project was set up on a schedule unlike any ever before undertaken in major dam construction. Various types of hazardous operations were involved, including unusually heavy excavation, extensive grouting, railroad and bridge construction, earth-moving equipment operations, road work, steel erection, and continuous placement of concrete 24 hours per day for several months. The high rate of speed at which they were performed made these operations more hazardous, so that all foremen and employees were continuously urged to exercise every effort to prevent accidents.

During the construction of the dam and powerhouse, 12,061,410 man-hours were worked, with 157 disabling injuries. Four of these injuries were fatal, and 11 resulted in permanent partial disability. A total loss of 34,649 man-days resulted from injuries; and the cumulative frequency rate was 13.0 accidents per million man-hours worked, while the severity rate was 2.87 days lost per 1,000 man-hours worked.

Because of the manpower shortage, the fast schedule of operations, and the high percentage of labor turn-over, the average physical condition of employees was probably lower than usual on TVA projects. The safety officer worked with the health officer and personnel representatives in placing physically handicapped persons on jobs which they could perform safely. All new employees were routed to the construction safety office, where they were instructed in the safety program and in the use of safety equipment in various operations. Powdermen were given written tests on the use and handling of explosives; and all powder foremen, powdermen, and powder helpers

were required to take a course in the safe use and handling of explosives.

Safety was promoted by means of bulletins, posters, and weekly and monthly safety meetings of employees in which management and supervisors participated. Accident prevention was studied, and a better understanding of cause and prevention was created. The central safety committee, headed by the project safety officer and composed of foremen and members of the various crafts, helped to make the job safe by regular patrol and inspection of work areas.

Construction in the reservoir area began early in 1942. This work consisted of adjustments to bridges and buildings and relocating roads and railroads in the reservoir and about the dam site. In order to help meet the schedule, much of the bridge work was done by contractors. The TVA construction forces relocated 9 miles of Southern Railway lines and constructed 7 miles of access railroad. Approximately 80 miles of highway was relocated and improved. During the 3,613,013 man-hours of exposure amassed by the construction forces in the reservoir, 29 injuries resulted, 2 of which were fatal. The frequency and severity rates were 8.0 and 4.26, respectively. The same type of safety program was effected for employees in reservoir work as for those at the dam.

The cooperation of all organizational units in adhering to safety policies helped to make the safety program at the Douglas project an effective one. Table 28 lists the figures on chargeable injury experience at this project.

TABLE 28.—*Chargeable injury experience in Douglas area*

Fiscal year	Man-hour exposure	Number of chargeable injuries				Number of days lost				Rates	
		Fatal	Permanent partial	Temporary	Total	Fatal	Permanent partial	Temporary	Total	Frequency [1]	Severity [2]
Dam construction, construction and maintenance, reservoir property management, reservoir clearance, land acquisition, and maps and surveys:											
1942 [3]	4,081,781	2	2	57	61	12,000	2,000	3,313	17,313	12.2	3.48
1[illegible]	[illegible]	4	13	114	131	24,000	4,140	4,598	32,738	11.3	2.53
1944	1,2[illegible]	------	1	4	5	--------	500	48	548	4.1	.45
1945 [4]	20,291	------	------	------	------	--------	-------	-------	--------	------	------
Total	17,774,612	6	16	175	197	36,000	6,640	7,959	50,599	11.1	2.85
Dam construction only	12,061,410	4	11	142	157	24,000	4,400	6,249	34,649	13.0	2.87

[1] Chargeable injuries per million man-hours of exposure.
[2] Days lost per thousand man-hours of exposure.
[3] Heavy construction started Feb. 2, 1942.
[4] July 1 to Dec. 31, 1944.

PROJECT AND PROPERTY PROTECTION IN WARTIME

Based on surveys by TVA, Federal Bureau of Investigation, Federal Power Commission, Army Internal Security Division, and Coast

Guard, a protective system was devised for Douglas by the TVA Public Safety Service and integrated with the protective system that embraced all TVA projects during the period of the national emergency caused by World War II.

Organization of the Douglas unit of TVA's uniformed protective force, the Public Safety Service, was begun February 1, 1942. From a nucleus of a chief, 1 sergeant, and 3 officers, the unit was expanded with increased construction activity and reached a peak in December 1942 with a chief, a captain, 5 sergeants, and 34 officers. At the war's end the unit had one lieutenant and nine officers.

From the beginning the Douglas project was considered a "controlled construction area," and the identification system of badges and passes in use at all TVA-controlled construction areas was instituted here. All employees working within the controlled construction area were fingerprinted by the Public Safety Service and issued fingerprint identity cards.

The controlled construction area was fenced, first with woven wire topped by strands of barbed wire, later with Cyclone-type fencing. Warning signs and barriers were placed on roads leading to TVA properties not within the controlled construction area. The Sevierville substation, supplying power to the construction project, was also fenced.

Protection against unauthorized approaches by water was obtained by Coast Guard designation of restricted zones above and below the dam and inauguration of 24-hour, 7-day-a-week water patrol on the lake in July 1943. The Coast Guard and TVA personnel cooperated until withdrawal of the military organization in October 1944.

Floodlighting was extensively used for protection. Such lights were generally directed outward from fences, gates, the substation, and switchyard, leaving the interior of the protected areas in shadow.

Before water mains were laid, protection against fire was obtained by placing water barrels in fire-danger areas and equipping a half-ton truck with a booster tank, force pump, extinguishers, and other equipment. Later, a total of 31 hydrants was installed and supplied from two 50,000-gallon storage tanks. An ADT fire-alarm system was used, and automatic sprinkler systems were placed in shops and the warehouse. Many employees were trained in fire prevention and suppression by the Public Safety Service fire fighter on duty. An agreement was made with the town of Sevierville for interchange of fire-fighting equipment and personnel in emergencies.

During the first 16 months of the job no serious fire occurred. In this time only 29 of the 65 fires reported caused damage, and this totaled only $280. A fire caused by lightning later destroyed the water filter plant, with damage of $3,057.50; and fires to two trailers in 1944 resulted in $1,603.08 damage.

In addition to the ADT system for reporting fires, communications relating to protection were handled by telephones at stationary Public Safety Service posts, a recall light atop a water-storage tank, and a siren at Public Safety Service headquarters for fire and other emergency signals.

Cooperation between TVA and other agencies, federal, state, and local, keynoted the protective service afforded Douglas, as well as all other TVA projects. The FBI, which had primary authority before

the outbreak of war for preventing espionage and sabotage, delegated responsibility for initial and preliminary investigation and reporting to the Public Safety Service. Arrangements were made by TVA for emergency aid, if needed, from the sheriffs of four counties nearest the project, from the State Highway Patrol, and from nearby local agencies. Later arrangements included the availability of United States Army detachments at Camp Forrest, Tenn., and the State Guard, if required. All TVA officers were commissioned as deputy sheriffs in Sevier County and made members of the Army Auxiliary Military Police. In nearly all arrangements there was a substantial degree of reciprocity. Fortunately, no use of the emergency plan was required; and no known act of sabotage was committed at Douglas during the war.

EMPLOYEE HOUSING

Most of the construction employees at Douglas Dam resided in established communities nearby; however, approximately 700 were housed at the site. TVA constructed a complete camp at the dam, with dormitories for single persons, then later established a trailer camp for families.

The main camp was located on the top of a broad hill at the north end of the concrete dam, about 1,000 feet from the bank of the French Broad River. On three sides the area was stripped for construction purposes, but the camp was sheltered on the north by a heavy growth of timber. The buildings located at this site included a group of dormitories, a cafeteria and food store, a community building, and a Negro recreation building. Figure 70 shows the arrangement of these buildings.

The main administration buildings were not located in the main camp group but at locations best suited to their use. They included a

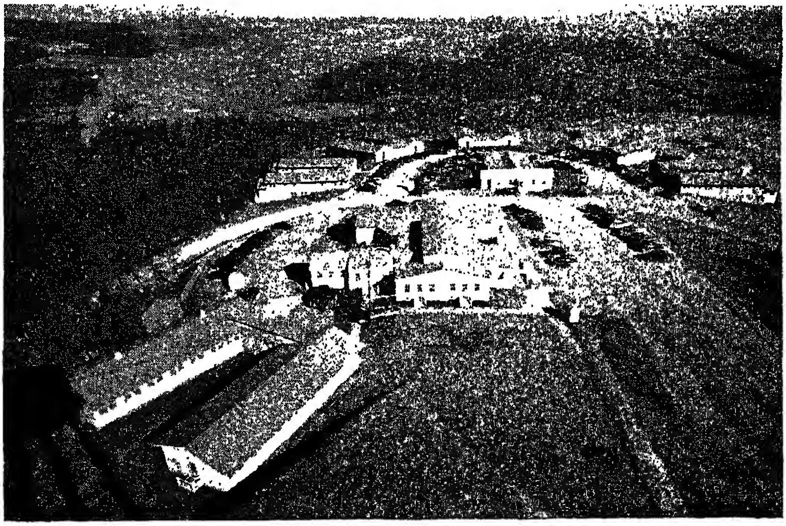


FIGURE 70.—*Douglas construction camp.*

combination personnel office and hospital building, a small commissary, the administration building, a fireproof vault for the storage of records, and a time office. Several smaller movable buildings, mounted on skids, were also provided and were used for office space and laboratory work by the field engineer, the electrical engineer, the materials engineer, the supervisor of foundation treatment, and the safety officer.

Construction of the camp started February 8 and was essentially complete by May 11, 1942.

Buildings

All buildings were of frame construction designed for temporary use, although they met high standards for shelter and protection and withstood normal wear and weathering for the construction period with a minimum of maintenance. In addition to those built new on the job, many of the Cherokee Dam buildings were dismantled, cut into panels, hauled to Douglas, and reassembled. The two projects are 23 miles apart.

Workmen's dormitories.—The workmen's dormitories were patterned after the dormitories first used at Guntersville Dam, which have since become standard with the TVA.[4] The buildings were one-story U-shaped structures that accommodated 60 men each. Sleeping quarters were in the wings of the U-sections, and the showers, toilets, and service rooms were in the connecting sections. Four of these dormitories for white workmen were transferred from Cherokee to Douglas, where the topography of the ground made it possible to add a basement structure to each wing. This basement provided 16 additional two-man rooms in each dormitory, making a total of 92 accommodations per building. A fifth dormitory for white workmen was built new, and a basement structure containing 20 rooms was added so that a total of 100 accommodations were provided. The Negro dormitory at Cherokee (consisting of only one wing) was transferred to Douglas, and the other wing was built. The completed camp provided dormitory housing for 468 white workmen and 60 Negroes. However, additional space for Negroes was required; and four tents, housing 10 men each, were erected near the dormitory.

Women's dormitory.—A dormitory was built for women employees. It was a two-wing building, with kitchen and dining room between, and contained 26 completely furnished single rooms.

Cafeteria.—The cafeteria building and equipment was moved from the Cherokee Dam construction camp and reassembled on new wood foundations. Moving started February 1, 1942, and meals were being served at Douglas by March 1, 1942.

The original building was remodeled to add a food market to accommodate the trailer village and to enlarge the Negro dining room. The main dining room accommodated 128 persons, and the enlarged Negro dining room 50 persons. The kitchen contained electric stoves, roasters and ovens, a bake shop, dishwashing equipment, and a large refrigerator.

Community building.—The camp manager's office and the recreation building at Cherokee Dam were moved to the Douglas site and com-

[4] Tennessee Valley Authority Technical Report No. 4, *The Guntersville Project*, 1941, p. 127.

bined to form the community building. Several additions were made so that the new building housed the camp office, post office, police office, a small commissary, a fire truck, lounge, toilets, barber shop, library, and reading room. The building was open at all times for project employees, and church services were held in the lounge on Sundays.

Hospital and personnel building.—Rooms in the hospital section of the building included two three-bed wards, two private rooms, doctor's quarters, surgery, sterilization room, general office, waiting room, first aid room, two doctors' offices, two examination rooms, X-ray room with an adjacent dark room, nurses' quarters, a kitchen with an adjoining staff dining room, and a number of rest rooms, closets, and storage rooms. One end of the main section was extended for a maternity ward and delivery room.

In the section occupied by the personnel staff were four interviewers offices, a general office, a waiting room, two classrooms separated by a sliding partition, rest rooms, and storage closets.

Administration building.—The administration building was 75 by 36 feet and contained a basement and two floors. The second floor was divided into space for the project accountant, cost engineer, bookkeepers, report engineer, and files. On the first floor were the offices of the project manager, construction superintendent, assistant construction superintendent, construction engineer, assistant construction engineer, office engineer, and the drafting and stenographic rooms. The basement of the building housed the office supplies, mail room, central files, blueprint equipment, telephone switchboard, showers, and offices for the geologist and foundation engineer.

Family housing

Because of the short period of construction and the location of Knoxville and several smaller towns within driving distance, the construction of family housing for workmen was not undertaken. However, a trailer camp was provided, which was located on a high ridge about one-fourth mile west of the main camp. Ninety-two trailers were operated by the TVA, of which 73 were owned by TVA

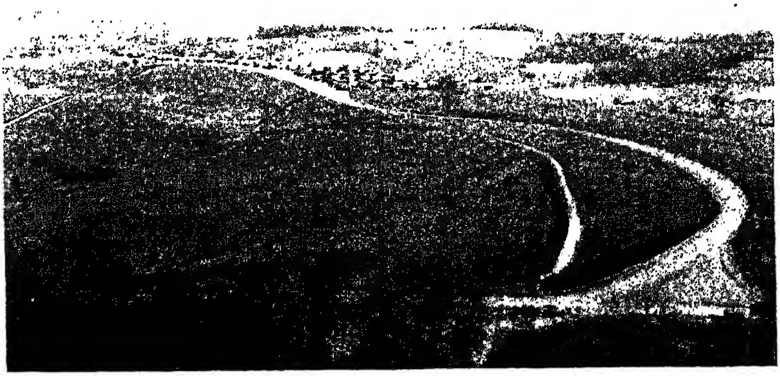


FIGURE 71.—*Aerial view of trailer camp.*

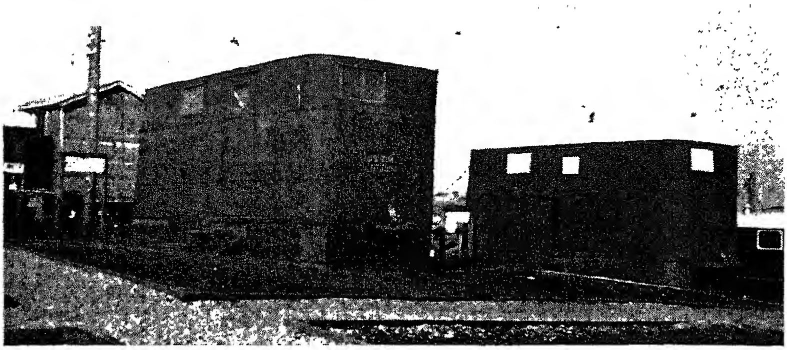


FIGURE 72.—*Bath trailers.*

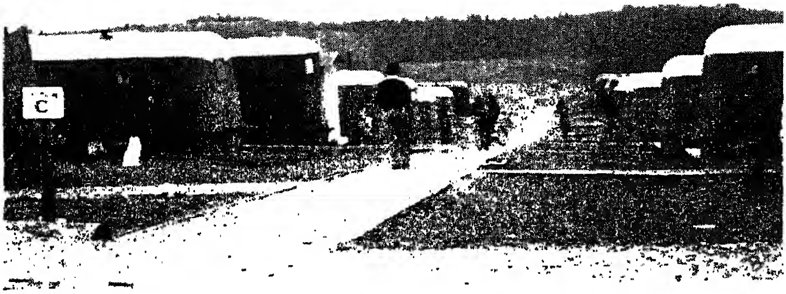


FIGURE 73.—*Village street and house trailers.*

and 19 were leased from the Farm Security Administration. Space was available for parking privately owned trailers. Community laundry, bath, and toilet trailers were provided as well as utility and sanitary connections.

Utilities

Roads.—All camp roads and parking areas were graded and surfaced with crushed rock, and the road leading to the administration building from the north access road was given a seal coat of asphalt and fine rock.

Water.—Fresh water for all activities was obtained from a spring located about 1 mile north of the dam and near the county road leading to Dandridge, Tenn. A permanent building was constructed to house the pumps and chlorinating equipment, from which the water was pumped to a 50,000-gallon steel storage tank located on top of the hill in the construction camp. The water distribution system was fed by gravity from the storage tank. The water supply was tested periodi-

cally as required by law, and the standards for drinking water as adopted by the United States Treasury Department and the Tennessee Department of Public Health were maintained.

Power.—Electric service was supplied by a 2,300-volt distribution system which connected with the main job substation located near the dam. The construction camp was virtually "all electric," and the distribution system was designed to meet all requirements. The buildings were electrically heated, and all cooking in the cafeteria was done by electricity.

Telephone.—Telephone service was provided from a switchboard in the administration building. During the construction peak three two-way trunk lines, leased from the Southern Bell Telephone & Telegraph Co., connected directly with the TVA switchboard in Knoxville. In addition, two two-way trunk lines were connected with the county service and one two-way trunk line was connected to Sevierville, Tenn.

Sewers.—The sewerage system serving the main camp, trailer camp, hospital, and administration building emptied into a 3,800-gallon concrete septic tank, the outfall passing through the construction plant yard and emptying into the river. The location and elevation of the time office necessitated separate sanitary sewer facilities, which were obtained by the construction of a small reinforced-concrete septic tank of 900-gallon capacity.

PROCUREMENT AND INSPECTION OF CONSTRUCTION MATERIALS AND EQUIPMENT

PROCUREMENT

This project was strictly a war emergency; and procurement procedure, especially for powerhouse and distribution equipment, was adapted to such requirements. Because of the necessity for completing Douglas Dam in the shortest time consistent with structural requirements, the project closely paralleled Cherokee Dam in design and equipment. This duplication made it possible to save many months on procurement. Congressional permission was again given TVA to waive the advertising requirements of section 9 (b) of the TVA Act and section 3709 of the Revised Statutes.

The War Production Board granted TVA a preference rating of A–1–c on the dam, reservoir, powerhouse, and installation of the generating units and accessories, but this rating was inadequate and was raised to AA–4 July 28, 1942. Transmission-line towers for construction power were given a rating of A–1–a. On January 11, 1943, a blanket rating order was issued by WPB which gave an AA–3 rating in lieu of the AA–4. Many special applications were filed for higher ratings. At times the priority problem was acute, particularly on equipment repair parts, and a special rating was secured for them. In approving the project, WPB specified the installation of one generating unit and turbine with accessories originally purchased for Cherokee Dam. The second unit was purchased from the same contractor.

In a number of cases competitive bidding was omitted, and some of the major items were contracted for on a negotiated basis. The contractors involved were those who had furnished or were furnishing

similar items for Cherokee Dam. On most items specifications were kept the same as for Cherokee. This duplication expedited the completion of Douglas project. In addition, there was an actual monetary saving inasmuch as the cost of such items probably would have been higher under competitive bidding.

Procurement for the Douglas project was in competition with some of the most important war requirements. This necessitated constant expediting, many appeals to WPB for allocations of strategic materials, and very close attention to details generally. Results obtained are reflected in the completion of the project in record time.

Many purchases were made, as previously, by direct contact with local and adjacent vendors, by memorandum orders, by unpriced orders, against requirement contracts, under contracts placed by other governmental agencies, and by letter requests. It was essential to utilize fully all available facilities to meet job requirements.

The procurement program necessitated the purchase of approximately $16,000,000 of equipment, materials, supplies, and services for the dam, reservoir, powerhouse, transmission lines, switchyard, and other features of the project. Practically all the construction work was done by force account. Contracts were let for concrete aggregate, relocation of highways, access roads, railroad access spurs, and other related activities. Cement was secured by making amendments to the long-term contracts made in 1935. Appendix E gives a list of the major purchases of materials and equipment.

INSPECTION AND TESTING

Organization

The inspection and testing service which the TVA established in the early years of its existence furnished regular inspection and testing for the equipment and materials used on this project. This service functioned in much the same manner as similar organizations in private and municipal practice. Two units performed this work, one for the inspection and laboratory testing of construction materials and one for the inspection of metals and equipment at point of manufacture.

Materials testing laboratories were maintained in Knoxville, to which samples of cement, concrete aggregate, reinforcing steel, metals of many kinds, paint, bitumen, and other construction materials were regularly sent. Cement inspectors and samplers were stationed at all mills furnishing cement for the projects, and they were charged with the responsibility of shipping only such cement as had been tested and approved in the Knoxville laboratories. Samples of highway and railroad construction materials, such as concrete aggregate and bituminous material, were tested either at the point of origin or at the Knoxville laboratories.

For the inspection of fabricated steel and equipment, district offices were established in four manufacturing centers, Pittsburgh, Philadelphia, Chicago, and Birmingham, from which inspectors covered various mills and shops furnishing materials, equipment, and parts purchased by the TVA. This service also included periodic reporting of progress on contracts and shipments and information when shipments were made.

These inspectors, at point of manufacture, witnessed tests of materials and when necessary sent samples to the Knoxville laboratories for check tests or more complete physical and chemical analyses. When possible, the inspector obtained copies of reports made by the producer and by private testing laboratories in addition to those made by the TVA.

If the contracts of the TVA required shop assembly of equipment the inspector checked such assembly and made certain that parts were properly match-marked and that drawings were prepared for use in field erection. Some standard materials and minor purchases were inspected by project engineers after delivery.

Specification and inspection procedure

Specifications were prepared by the division originating the purchase request, and the requisition was classified as "inspection by inspection division" or "inspection at destination." This statement was then incorporated in the award of a contract, and where inspection was to be made at the source the contractor was usually instructed to confer with the head of the inspection and testing work on matters relating to inspection.

Immediately following the award, detailed instructions were mailed to the contractor stating what materials or equipment were subject to shop inspection; and instructions were issued to the contractor for furnishing the TVA with copies of orders to subcontractors and also for notifying the TVA when an inspector would be needed. From copies of orders for materials made by the contractor TVA determined whether inspection would be conducted at the plants of the subcontractors or after arrival at the plant of the main contractor.

During progress of the work the inspectors furnished periodic reports showing the quality of the materials, workmanship, and data from which a semimonthly status sheet was issued from the central office at Knoxville showing the contract delivery dates and the inspector's estimate of the actual delivery date. When each important contract assigned for inspection was completed, a final report was issued showing that materials or equipment satisfied the specifications under which they were purchased.

CONSTRUCTION ACTIVITIES

ORGANIZATION

As shown by the organization chart (fig. 74), the project manager coordinated, directed, and supervised the engineering, construction, and accounting organizations at the dam site, acting through the construction engineer, the construction superintendent, and the project accountant, respectively. In addition, he was responsible for coordination of the reservoir work, which included clearing, road relocation and construction, utility relocations, and backwater protection.

Engineering organization

Engineering at the project was coordinated and supervised by the construction engineer and the assistant construction engineer, who

were assisted by office, field, materials, and electrical engineers and their staffs.

The office engineering section prepared estimates, computed progress and final quantities, prepared final record drawings, made construction schedules, and designed forms and special equipment, methods, and structures required for the construction of the dam.

The field engineering section performed all surveying and layout for all parts of the dam construction and inspected the installation of structural, mechanical, and architectural features, including acceptance tests on permanent equipment. In addition, this section directed the foundation exploration and treatment work and the rolled earth fill operations. During peak construction seven three- and four-man field parties were required. Because of the magnitude and importance of the foundation treatment, the entire operation, which included the engineering, planning, and inspection of the work, as well as the direction of the construction drill crews, was directed by a civil engineer reporting to the field engineer.

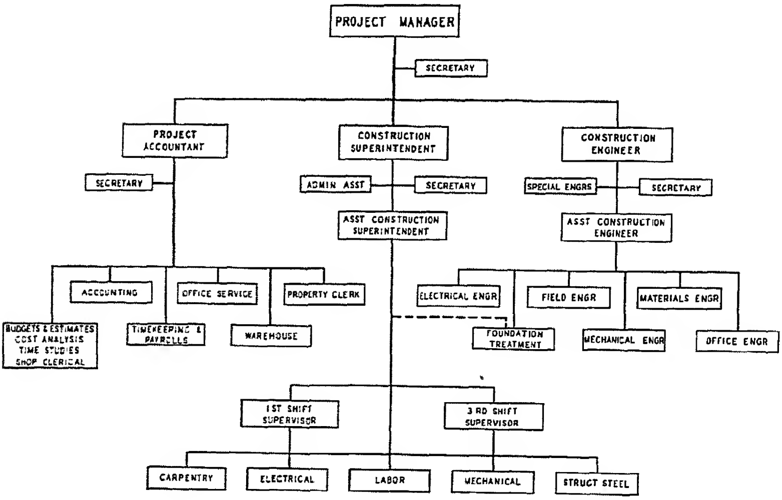


FIGURE 74.—*Organization chart.*

The design of concrete mixes, the inspection of concrete mixing and placing, and the testing of concrete aggregate and other materials were handled by the materials engineering section in connection with the operation of the concrete laboratory.

The electrical engineer inspected the installation of conduit, power and control wiring, switchyard equipment and powerhouse electrical equipment, and conducted final acceptance tests.

Engineering studies

Because of the rapid construction schedule, a continuous program of studies and planning was maintained. Major construction operations were studied in order to find faster, more efficient and economical methods; some of these methods involved the handling of various

heavy pieces of equipment, such as penstocks, sluice gates, powerhouse crane, spillway gates, turbines, and generators. The river-control system was planned carefully to meet construction demands, particularly methods of stage diversion and closure operations. The scheduling and methods for placing concrete required many studies to meet the construction schedule.

Engineering control layout

The primary horizontal control system for the dam included the axis, or base line, permanently established by two monuments on the line on each side of the river, and additional parallel reference lines 400 and 800 feet upstream and 400 feet downstream from the base line. The primary grid was monumented and tied to and coordinated with the control survey of the surrounding region, the Tennessee State system of rectangular coordinates. Bench marks were established at strategic points.

The secondary or construction grid system was laid out from the primary control grid. The main grid on the secondary system consisted of target range lines normal to the base line of the dam and intersecting it 1 foot north of the center line of each block and on the center line of the penstocks and generating units, intersected by target ranges parallel to the base line. For the dam, a line was placed 14 feet downstream from the base line; for the powerhouse, a range was placed 30 feet downstream from the center line of the unit; and a range was placed 312.4 feet downstream from the base line to tie in the lower end of the spillway apron.

To set working points for the erection of concrete forms and other construction features, transit lines were established by "bucking in" on the target lines, first on the line parallel to and next on the line normal to the base line. These points were marked with brass tacks in lead plugs set in the concrete. Elevations were carried up from bench marks embedded in the lower pours.

Permanent brass monuments were set at several points in the top of the dam, on which precise alinement points and elevations were established. Permanent bronze bench marks were also set at the headwater and tailwater gage wells.

RIVER DIVERSION

The construction of Douglas Dam was accomplished by making three river diversions: the first through a channel excavated along the high rock bluff of the south bank, the second through blocks 22 and 23 left low at elevation 878, and the third through the eight permanent sluices in the spillway section of the dam.

Cofferdams were of log crib construction and required 714,966 linear feet of log timber. Of this total, 193,884 linear feet was obtained from the TVA's reservoir clearance operations and the balance was purchased from outside sources.

Stage 1

The diversion channel excavated along the high rock bluff of the south bank (fig. 75) permitted the construction of a log-crib cofferdam enclosing the greater portion of the concrete dam from the north abutment to and including block 24. This cofferdam was designed to protect the working area against a flow of 60,000 cubic feet per

second, or a flood frequency of once in 7½ years during the crop season.

The original plan for construction of the stage 1 cofferdam was to build the river arm of the cofferdam while excavation for the diver-

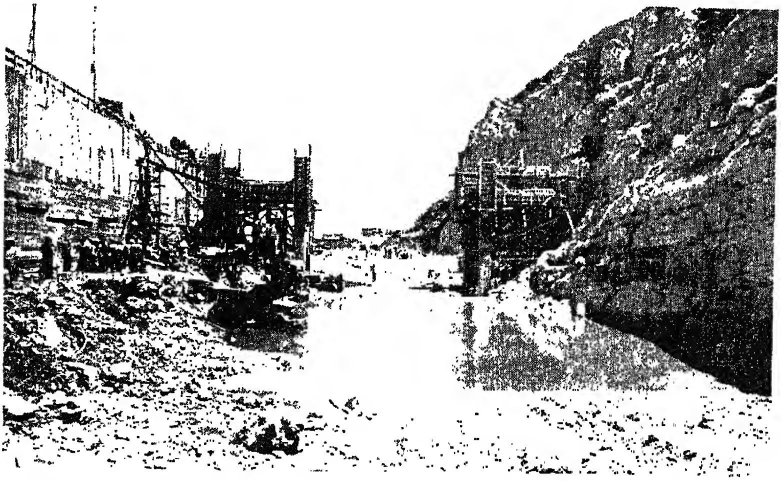


FIGURE 75.—*Looking east along center of diversion channel at Douglas Dam with cofferdam on left and Trotters Bluff on right.*

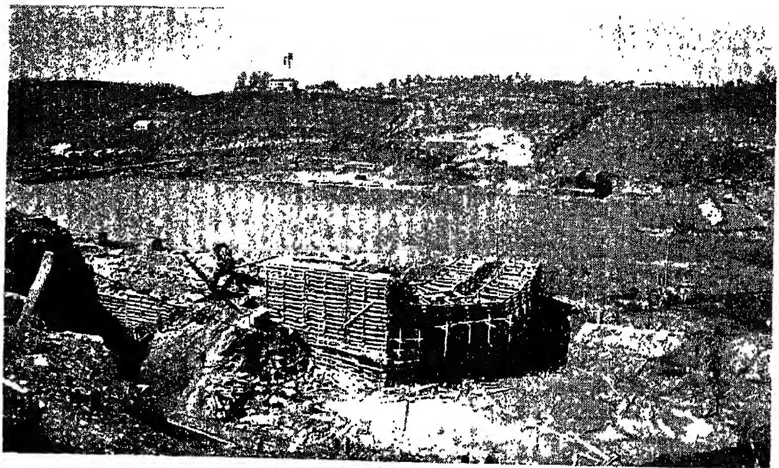


FIGURE 76.—*Construction of temporary upstream and downstream dikes and river arm for stage 1 cofferdam.*

sion channel was in progress, and when these two operations were near completion, upstream and downstream temporary dikes were to be built and the upstream and downstream arms of the cofferdam were to be erected in the dry. However, because of adverse weather condi-

tions, the restricted working space, and the large amount of rock excavation required in the diversion channel, a modification of the original plan was made to prevent delay within the stage 1 construction area.

The revised plan extended the temporary upstream and downstream dikes to approximately the middle of the river (fig. 76), where they were connected by a temporary dike parallel to the river. The enclosure thus formed unwatered the powerhouse area and permitted foundation excavation and erection of the construction trestle and log-crib cofferdam. When the diversion channel was completed, the upstream and downstream dikes were extended toward the south bank, and the upstream and downstream cofferdam arms were extended and tied to the river arm already completed.

Dikes.—The first dikes constructed were two on the left bank of the river for enclosing the upstream and downstream elbows of the first-stage cofferdam river arm. The second dike operation was the system enclosing the intake and powerhouse area to permit foundation excavation prior to the first-stage river diversion. Temporary dikes were composed of rock and clay with the outside slopes of the upstream and river arms covered with a protective blanket of quarry-run rock.

Cofferdam.—The stage 1 cofferdam was constructed as shown in figure 45. In the upstream arm at that section of the river channel where existing bedrock was below elevation 864, the design required that the crib width be increased from 42 to 46 feet, and 20 cribs of the 46-foot width were built. Small cribs, 16 feet wide, tied the cofferdam into the north river bank. The average height of the upstream arm was about 40 feet; the river arm, about 33 feet; and the downstream arm, about 26 feet.

Sheathing was placed on both faces of the clay chamber and on the outside waterway face. The sheathing was placed after the rock fill was completed to prevent buckling that would have occurred as a result of crib settlement while being filled with rock. Two flooding sluiceways were built in the downstream arm, and the arm was tied to the north bank with a rolled clay-filled dike. Two cribs were temporarily omitted from the upstream arm to provide a passage for hauling excavated material to the upstream waste dump. This gap was bridged to permit passage of trucks and mobile equipment across the top of the cofferdam cribs.

Crib logs were trimmed at the ends to secure flat bearing surfaces at the corners. Holes were drilled through the logs with air-operated drills, and ¾-inch-round drift pins 18 inches long were driven into these holes with an air-operated hammer equipped with a driving head. A stiffleg derrick made of 4-inch pipe and operated with an air hoist was used to handle and place the logs in position. At the section of the cofferdam located in the river channel, some difficulty was encountered in fitting the base logs to the bedrock, and where necessary a 1- by 2-foot concrete seal was placed at the bottom of the outer face of the clay chamber.

Diversion channel.—The clear opening of the channel between the cofferdam river arm and excavated face of the rock bluff was an average of 114 feet in width. Excavation in the channel extended from approximately 25 feet upstream from the base line to the downstream end of the spillway apron. The south two-thirds of the channel was

excavated to approximate final grade, but the area under block 25 and half of block 26 was not excavated to insure the stability of the cofferdam river arm. However, in block 25 excavation for the construction trestle footings was carried to sound rock; and to protect the crib cofferdam at this point, special timber cribs were constructed and backfilled with rock after the tower columns were poured.

The upstream entrance and downstream discharge sections of the diversion channel were excavated to a 500-foot radius. Barriers of earth about 25 feet wide were left at the inlet and discharge ends of the channel until excavation in the channel and trestle towers 1 and 2 was completed. These barriers were then removed by blasting. Excavation for the diversion channel and the river arm of the cofferdam was begun February 8, 1942, and the diversion was made May 5, 1942.

Cofferdam maintenance.—The temporary dike system was completed May 7, 1942, and the river bottom was exposed May 10. As excavation within the powerhouse area progressed considerable difficulty was encountered with leakage through solution channels in the rock

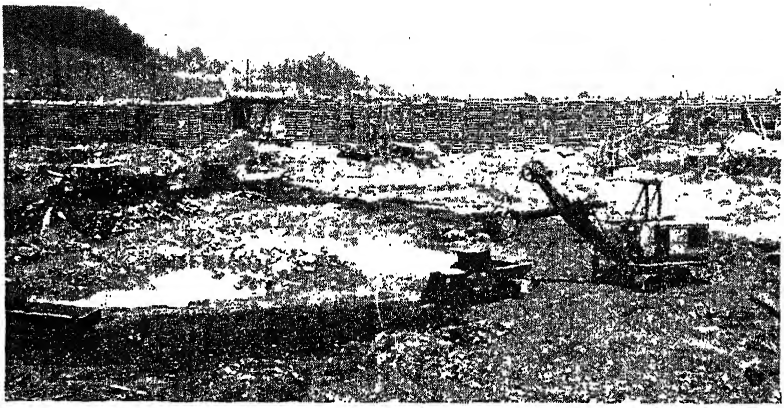


FIGURE 77.—*Excavating in spillway area, looking east.*

under the dikes, and pumping facilities in addition to those used for unwatering were required. Asphalt grouting was used to check the worst leakage and earth blankets were placed, extending approximately 500 feet both upstream and downstream from the dikes, in an attempt to reduce water percolation and leakage into the working area.

For a considerable period, 30 pumps discharging over 100,000 gallons per minute were in constant operation to keep the cofferdam area dewatered sufficiently to permit excavation. Pumping stations were constructed at temporary sumps excavated at various points inside the cofferdam. Heavy timber shelters were erected around the pumps to prevent damage from blasting, and the water was discharged into timber flumes located on the outside of both the upstream and downstream sides of the cofferdam. These flumes carried the water to the diversion channel. Figure 79 shows the pumping stations along the upstream arm of the cofferdam.

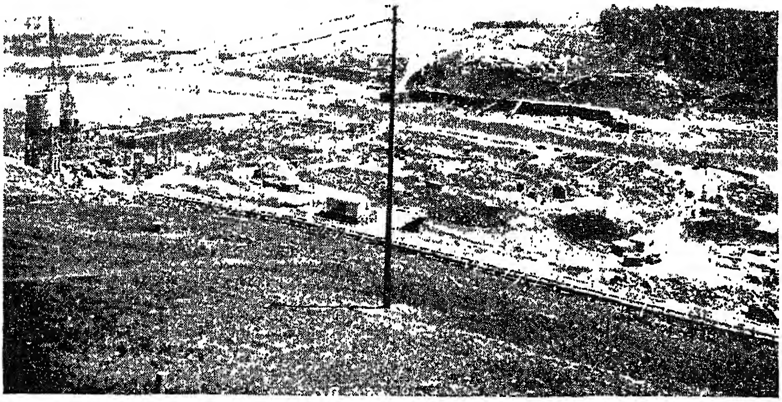


FIGURE 78.—*Excavation progress within cofferdam, looking upstream from main office on right bank, showing mixer plant silo at left.*

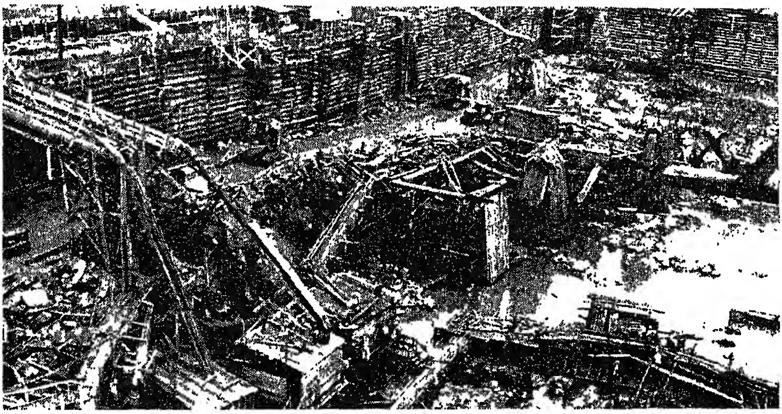


FIGURE 79.—*Pumping stations along upstream arm of cofferdam.*

Grouting of the stage-1 cofferdam developed into a major operation; and despite the extensive grouting program, water inflow continued during the entire period of cofferdam use. Large quantities of asphalt, cement, clay, and some sawdust were used with moderate success; and grouting was continuous from April 20, 1942, to November 10, 1942.

Stage 2

The stage-2 cofferdam permitted the unwatering of the area occupied by spillway blocks 25, 26, 27, and 28, originally the location of the stage-1 diversion channel. The varying heights of the cofferdam and features of the stage-2 river diversion were based on hydraulic studies with an assumed river discharge of 30,000 cubic feet per second, or

a flood probability of once in 3½ years for the month of January. The river was diverted through blocks 22 and 23 left low at elevation 878 and supplemented by the permanent sluices in blocks 18, 19, 20, and 21.

Dikes.—A temporary dike across the stage 1 diversion channel was built approximately 300 feet upstream from the dam, and the river was diverted through the low blocks December 13, 1942. This dike was constructed during a river discharge of about 8,000 cubic feet per second, and large-size rock was required to hold the dike against this flow. Old steel girders were placed across the channel to help hold the rock in place. Before closing the dike, the upstream and downstream arms of stage 1 cofferdam were removed; and a diversion channel was dug through the earth blankets used for sealing the stage 1 cofferdam. A dike barrier across the downstream channel was opened by blasting prior to closing the newly constructed upstream dike. Diversion was made December 13, 1942.

Immediately following river diversion a dike was built from the downstream cofferdam river arm across the stage 1 diversion channel to the south bank of the river, which completed the enclosure of the stage 2 area. Unwatering began December 15, 1942, and the river bed was exposed December 17, 1942.

Cofferdam.—Construction of the river arm for the stage 2 cofferdam began as soon as concreting had progressed sufficiently in spillway block 24. The log cribs for the river arm were built in two sections. The downstream section extended from the spillway face of block 24 to a point about 260 feet downstream, where it was tied into the river arm of stage 1 cofferdam. The upstream section extended from a wing wall on the upstream face of block 24 to a junction with the upstream arm of stage 1 cofferdam.

The elbow sections of the stage 1 river arms where they joined the ends of stage 2 river arm were incorporated as part of the stage 2 cofferdam. The upstream arm of stage 2 cofferdam consisted of two parallel rock-filled chambers with a clay embankment on the upstream side for a water seal. No downstream arm was contructed, but the downstream dike was raised to secure ample protection. Crib design for the stage 2 cofferdam was similar to that in stage 1, having outside rock-filled chambers and a central clay-filled chamber differing only in dimensions and arrangements.

Beyond the limit of the spillway apron there were several large cavities in the bedrock on which the downstream river arm was to rest. These cavities were filled with concrete both for support and for reduction of leakage. At the junction of the river arm with the stage 1 river arm a single rock-filled crib in stage 1 was cleaned out, sheathed, and backfilled with clay to obtain a continuous clay core. In that portion of the river arm resting on the spillway apron a hand-formed concrete seal was placed along the base of the clay compartment on the water side, and wood-plate water breaks were placed around the logs crossing the clay chamber.

The first operation in the upstream section of the river arm was the preparation of the foundation. A large cavity in the rock was cleaned out and filled with concrete. The space between the upstream face of block 24 and the excavated rock face was also filled with con-

crete to the level of the original river bedrock. The tie to the upstream arm of the stage 1 cofferdam was effected in the same manner as that at the downstream section. The tie at the concrete dam was made by extending the end wall of the sluice trashrack a distance of 26 feet upstream from the face of block 24 and raising its height to elevation 906. The cribs ended a distance of 23 feet from the face of block 24 and were attached to the wall with timber posts and bolts. This was done to permit installation of the trashrack in the sluice opening of block 24.

Cofferdam maintenance.—There was considerable leakage through the upstream dike; and to reduce water interference to a minimum, a second clay dike was constructed approximately 100 feet upstream from the log-crib structure. The enclosure thus formed confined water flowing in through the dike to an area outside the construction operations. Three pumping stations were established: one in the upstream confined pool, one at tower 2 of the construction bridge, and one at the downstream dike. With these provisions little difficulty because of the pressure of water was experienced, and grouting was confined to localized leaks; large-scale grouting was unnecessary.

Auxiliary cofferdam bulkhead

An auxiliary cofferdam bulkhead consisting of reinforced-concrete piers, poured as part of blocks 25, 26, and 27, and provided with timber stop logs, was constructed along the upstream face of the dam. Its purpose was to give additional protection against floods and to permit early removal of the upstream arm of the stage 2 cofferdam. This bulkhead is shown in figure 80. The upstream section of blocks 25, 26, and 27 were poured to elevation 872.4, forming a base for the piers which were poured in two lifts: the first to elevation 884, and the second to top elevation 906.

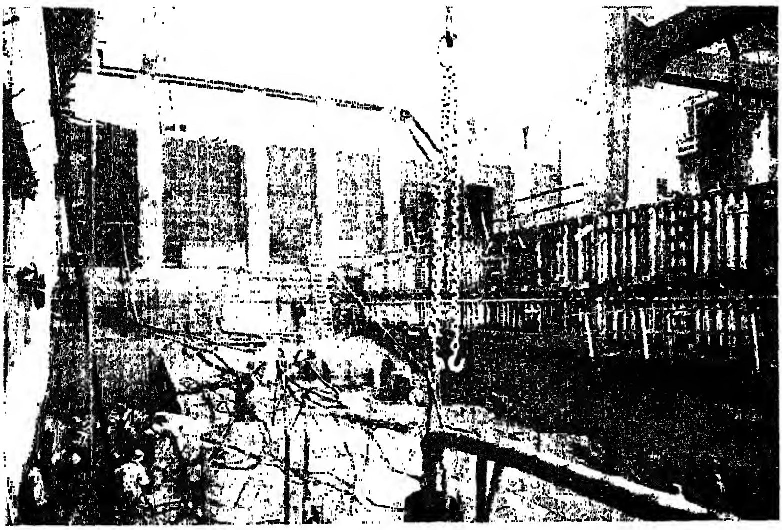


FIGURE 80.—*Looking upstream at bulkhead of the second-stage cofferdam.*

To complete the piers quickly, forms were built at the carpenter shop with the required steel reinforcement installed and held rigidly in position over wires and bolts. By the use of this method, construction of the 10 piers was completed in 4 days. The timber stop-log bulkheads were installed January 24, 1943, which completed the auxiliary cofferdam and permitted removal of the upstream arm of the stage 2 cofferdam. The pumping station in the upstream confined pool was removed February 4, 1943. The timber stop logs in the auxiliary cofferdam bulkhead covering the sluice in blocks 25, 26, and 27 were removed February 9, 1943.

Final closure

Final closure was made by cutting off the river flow through blocks 22 and 23 and concreting these blocks (fig. 81) to complete the dam. The final river diversion was effected February 14, 1943, through the eight permanent sluices in the spillway section. The closure across blocks 22 and 23 was accomplished by placing concrete gate bulkheads along the upstream face of the dam.

FIGURE 81.—*Final closure—placing concrete in block 22.*

Design.—The capacity of the eight sluices is 12,000 cubic feet per second at elevation 896, the headwater elevation used for the closure design. Additional designs were prepared for making the closure at 15,000 cubic feet per second if necessary. The concrete gates were lowered into slots provided by vertical steel cantilever beams previously grouted into pockets embedded in the concrete block. Design of the beams permitted a maximum stress with headwater at elevation 891.5 corresponding to a flow of 9,600 cubic feet per second. To close against [illegible] feet per second, the vertical beams were braced with pipe struts; and by taking advantage of the reservoir storage, there was time to place these struts before the pool reached elevation 891.5.

When the closure was completed, the vertical steel beams were extended to elevation 903 and timber stop logs were placed on top of

the concrete gates for the 7-foot extension. The added height provided protection against 15,000 cubic feet per second.

The concrete bulkhead gates were sealed with cinders, and a sandbag dike placed a few feet downstream from the closure bulkhead confined the small amount of leakage for pumping. The surface of the old concrete was thoroughly cleaned and scarified before placing the forms. On February 18, the upper timber stop logs were removed, and the permanent sluices were closed the next day for reservoir storage. This date was 1 year and 19 days after construction was started on February 2, 1942.

Cofferdam grouting

The grouting program for sealing leaks under the cofferdam structure was carried on concurrently with the dam construction. As excavation deepened, the increased hydraulic head caused more leakage. Grouting for the first-stage cofferdam was in progress from April 1942 to October 1942—nearly its entire period of use. Complete sealing of the honeycombed rock was never attained, and continuous large-scale pumping supplemented the grouting.

Grout materials.—Asphalt proved the most effective material for sealing the larger solution cavities and seams. A large quantity of cement-clay grout was also used in volumetric proportion of one part cement to three parts clay. Sawdust, in varying proportions, was frequently added to the cement-clay mixture; and calcium chloride in amount of 3 percent by weight of cement was added to practically all cement-clay grout mixtures to accelerate setting time. Neat cement grout with water-cement ratios from 2.0 to 0.6 was occasionally used for small leaks.

Procedure.—Asphalt was heated in portable kettles and pumped into 3-inch diamond drill holes through a 2-inch pipe fed with air-driven pumps. Two types of pumps were used, one a rotary and the other a piston with iron ball valves. The latter type proved the most satisfactory. Standard grout packers were not used for asphalt grouting, as they could not be recovered. A substitute packer, made by wrapping a short length of 2-inch pipe with burlap to form a snug fit in the hole casing, was adopted. Cement-clay grout was placed with standard cement grouting equipment, and holes were grouted progressively from bottom to top. The maximum pressure was 35 pounds per square inch for the lower levels, with pressures reduced to as little as 5 pounds per square inch in special cases nearer the surface.

Grouting pattern.—The general pattern of grouting was a line of 3-inch holes located along the central clay chamber of the cofferdam. The initial spacing of these holes was 20 feet on centers, and they were drilled 20 feet into rock. Following the grouting of these holes, the spacing was reduced, and hole depths were increased to reach a zone relatively free from cavities. Some holes were drilled 60 feet into rock, and the final spacing of some was progressively reduced to 2.5 feet. In addition to this line of holes, numerous holes were drilled inside and outside of the cofferdam where fluorescein-dye tests and geological information indicated their advisability.

The following quantities of grout material were placed for cofferdam sealing:

Item	Stage 1	Stage 2
Drilling: Bortz diamond (3-inch)	34,445.6 linear feet	2,376.2 linear feet.
Grout materials:		
Asphalt and pitch	181,150 cubic feet	2,860 cubic feet.
Cement	54,625 cubic feet	510 cubic feet.
Clay	106,584 cubic feet	1,540 cubic feet.
Sawdust	22,926 cubic feet	
Calcium chloride	95,506 cubic feet	

Cofferdam flooding

During the month of December 1942, excessive rainfall occurred in the drainage basin of the French Broad River. As a result, a flood crest of 71,500 cubic feet per second was obtained at the dam site December 30, 1942. Between December 29, 1942, and January 2, 1943, the stage 2 cofferdam was flooded; but delay and damage because of high water was almost entirely confined to the second-stage construction area.

Temporary timber bulkheads were placed in front of the intake openings of penstocks 1, 2, and 3, and these bulkheads were braced with a steel beam on the downstream face designed for a possible headwater elevation of 920 feet. A timber bulkhead was also placed in the exposed opening of the sluice gate operating gallery at the south face of block 21, and the tops of the sluice air intake pipes were capped to prevent water from being forced up these pipes from below.

In the powerhouse the draft tubes were filled to the top of the temporary overflow pipes, which reduced the pressure on the draft tube gates. A gasoline-operated pump was placed in the unit 2 draft tube to provide pumping facilities in the event of power failure. These precautions proved adequate and no flooding of the powerhouse occurred.

Both the upstream and downstream dikes, together with the partly completed upstream arm of the stage 2 cofferdam, were swept away by the floodwaters. The downstream river arm held firm, although a considerable portion of the clay in the central chamber was washed out. Reconstruction began January 1, 1943, against a river flow of 30,000 cubic feet per second; and work was resumed with the unwatering of the cofferdam January 11, 1943.

A summary of cost for the diversion and care of water is given in table 29.

TABLE 29.—*Timber crib cofferdams—summary of costs for diversion and care of water*

Item	Stage 1 cofferdam	Stage 2 cofferdam
Area enclosed, square feet	280, 960	88, 000
Rock fill, cubic yards	47, 829	(1)
Clay fill, cubic yards	(1)	(1)
Rock fill (dike), cubic yards	56, 336	
Earth fill (dike), cubic yards	(1)	
Logs, linear feet	115, 332	29, 526
Lumber, board feet	873, 530	54, 660
Maintenance, days	224	57
Cost		
Earth dike erection	$240, 274	
Earth dike removal	178, 901	
Timber crib:		
Timber erection	544, 351	$111, 450
Place fill	114, 070	24, 251
Crib and fill removal	52, 568	21, 338
Sluiceway protection		25, 281
Grouting	532, 241	56, 547
Maintenance	771, 277	122, 844
Flood costs	30, 549	69, 302
Total cost	2, 464, 231	431, 013

[1] Spoil material used.

FOUNDATION EXPLORATION

Geology

The foundation rock at the site of the concrete dam is composed of dolomitic limestone of the Knox formation, which extends southward along the reservoir rim for a distance of 1,500 feet. At this point a relatively narrow band of limestone of the Lenoir formation begins and continues to a contact with the Athens shale on the south. The contact between the Lenoir limestone and the Athens shale is under the north end of saddle dam No. 1. The foundation for the remaining saddle dams is shale.

At the dam site the bedding of the dolomitic limestone dips to the south at an angle of approximately 20°. The strike of the rock is almost parallel to the flow of the river, which makes the base line of the dam almost normal to the strike of the rock.

Exploratory drilling

Preliminary studies for the location of Douglas Dam were conducted intermittently between 1937 and 1942. These included geologic examinations of the site and mapping of the regional structure and stratigraphy.

The site chosen was at mile 32.3 above the mouth of the French Broad River. In 1939, auger borings were made to determine the extent of the overburden and ground-water conditions; and in 1941, core drilling was started.

The exploratory drilling completed prior to the start of construction gave a general picture of the foundation, including the approximate elevation of sound unweathered rock. It also indicated that in the river bed deep solution and weathering caused the formation of an extensive honeycomb of cavities and fissures, which apparently had not developed into any regular system of cavitation.

The preliminary exploratory drilling at the dam site in 1941 consisted of 3½-inch diamond core drill holes on three parallel ranges

spaced 100 feet apart approximately parallel to the base line of the dam. Holes were drilled on these ranges at 100-foot intervals, except at the south abutment where a few holes were drilled at 50-foot intervals. The holes penetrated from 100 to 250 feet into bedrock. Drilling was discontinued November 22, 1941, and was resumed January 17, 1942, two weeks prior to the start of actual construction operations February 2, 1942.

In addition to the preliminary drilling, considerable diamond drilling was done during actual construction operations to develop accurate geologic sections. These sections were used to determine the final excavation grades and for planning the general program of foundation treatment. A number of 42-inch shot drill holes were drilled to check questionable areas by visual inspection, locating them so that they would be used in the adopted plan for treatment.

Foundation conditions

In the Knox dolomite formation the thick beds are susceptible to solution by the action of ground water, resulting in the formation, in the upper 60 feet, of extensive cavities and fissures; those parallel to the strike were especially developed. This condition was general over the entire dam site. Underlying the weathered rock was solid unweathered dolomite, which formed the actual foundation of the concrete dam. Figure 82 shows a profile of the concrete dam and abutments and indicates the weathered condition of the rock.

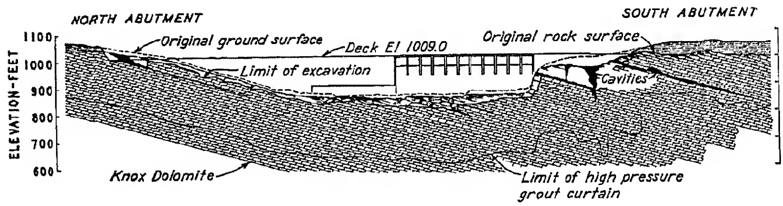


FIGURE 82.—*Profile of excavation.*

North abutment.—The natural slope of the north river bank at the dam site was nearly parallel to the dip of the foundation rock. Weathering in the upper strata of bedrock was fairly uniform and averaged from 8 to 10 feet in depth over most of the area. A thin, continuous bed of insoluble cherty shale was found approximately 40 feet below the surface of the unweathered rock; and above the shale bed there was an extensive partly clay filled cavity. The location of the cavity is shown in figure 83, with the outline of the base of the dam superimposed upon it. Figure 84 shows details of the cavity.

It was intercepted by several strike joint cavities running normal to the axis of the dam, which formed enlargements in the main cave, making the maximum height of the cave approximately 5½ feet. About 40 feet of sound rock existed above the roof of the cavity after the excavation for the dam had been carried to final grades, the removal of which was not considered necessary or desirable.

Powerhouse, intake, and spillway.—Under the powerhouse, intake, and spillway sections the honeycombed condition increased in depth toward the south bank of the river. The greatest depth was reached

under the spillway, where sound unweathered rock was about 60 feet deep at elevation 810. From this point southward to the end of the spillway the elevation of sound foundation rock was higher, and the south end of the spillway was defined by an almost vertical rock bluff extending to elevation 922.

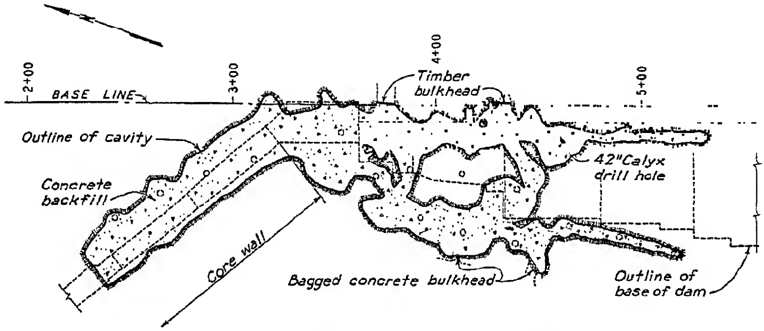


FIGURE 83.—*Plan of north abutment cavity.*

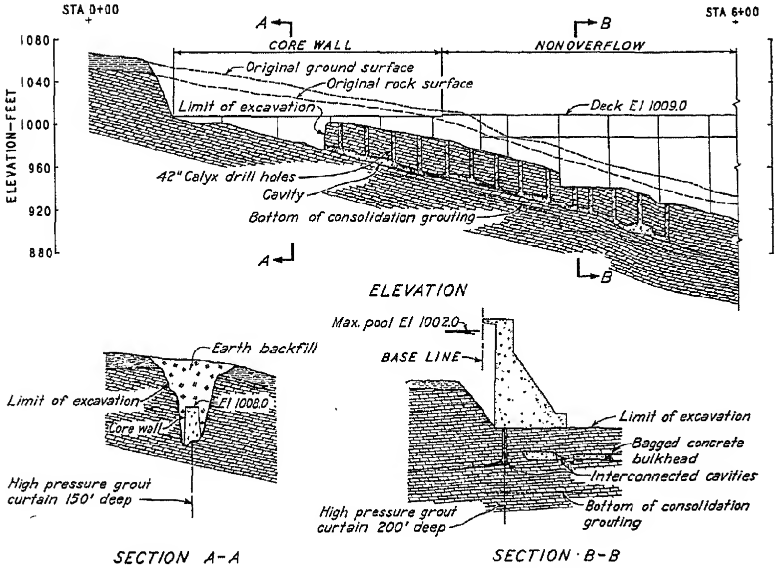


FIGURE 84.—*Details of north abutment cavity.*

Large cavities were found along many beds and were interconnected by cavities extending along both strike and dip joints. Some of the cavities were large enough to be termed "caves" and were continuous for long distances, principally along the strike of the rock. The cavities were partly filled with clay, sand, and gravel, and some of the foundation was so badly weathered as to present the appearance of clay and gravel in which nested huge floating boulders.

South abutment.—Under the south abutment prominent deeply weathered strike joint solution channels extended through the foundation normal to the dam; and, in addition, there were less pronounced bedding cavities. Terrace clay and gravel were present in the cavities. A solid bedding plane of dolomite sloped from elevation 922 at the south end of the spillway to elevation 875 near the south end of the concrete dam.

A large bedding cavity, starting under the end of the south nonoverflow section of the concrete dam, extended southward for about 700 feet into the rim. The cave was partially filled, and at some points tightly filled with clay, sand, and terrace gravel, with the terrace gravel normally in lenses. The elevation of the cave varied from 963 at the entrance to 790 at the sound end. At the entrance and for about 100 feet the average height of the cave was approximately 3 feet, enlarging to 25 feet in height for a distance of 50 feet. For the next

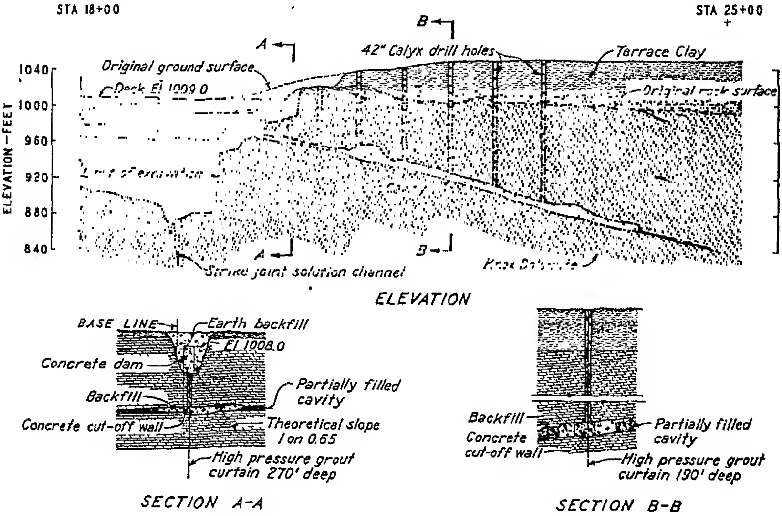


FIGURE 85.—*Details of south abutment cavity.*

250 feet the cavity averaged 7 feet in height and then abruptly narrowed to approximately 6 inches. The entrance of the cavity was exposed during excavation in the south abutment. A number of 42-inch shot drill holes drilled through it from the natural ground surface indicated that very little weathering or solution existed above or below the cavity. Figure 85 shows the details of the bedding cavity and the location of the large shot drill holes.

Reservoir rim and saddle dams.—Except for the one cave at the end of the concrete dam, there was very little evidence of solution and weathering in the rocks of the south rim. The unweathered shale was not absolutely impervious as core drilling encountered streams of water at relatively low regions. The shales were somewhat calcareous and contained a few interbedded layers of shaly limestone.

EXCAVATION

Work started February 2, 1942, in the north abutment, and a few days later removal of the alluvial flood plain along the south bank of the river was started. This area was used as a diversion channel during the first-stage operations. Most of the excavation had been completed by September 1942.

The powerhouse section and a major portion of the spillway section were located in the river bed, and excavation here was dependent on the construction of the first-stage cofferdam and diversion of the river flow. To avoid delay, a temporary earth dike was constructed around the intake and powerhouse section, permitting work to proceed before the cofferdam was completed. River diversion was effected May 5, 1942, and excavation operations were then extended to include the first eight blocks of the spillway. The work within the cofferdam area progressed from north to south, and as fast as final grades or sound rock had been established the concrete footings for the construction trestle were poured.

Earth excavation.—Overburden in the north abutment area and in the river bed was very thin. The flood plains along both banks of the river and the overburden in the south abutment contained nearly all the 172,300 cubic yards of earth that was removed. A maximum cut of 50 feet was necessary to expose weathered rock in the south abutment.

The material from the north abutment and river bed sections was used for fills in the construction yard, temporary dikes, and cofferdam crib filling. From the south abutment it was wasted upstream and later used for backfilling around the concrete dam. Under the earth saddle dams the earth excavation consisted only of stripping the vegetable humus from the surface, except for saddle dam No. 1 where a shallow cut-off trench was excavated.

All material was removed with power shovels and hauled to points of use or waste disposal by trucks and tractor-drawn dump wagons.

Rock excavation.—The rock was drilled and blasted in successive 10-foot depths until sound unweathered rock was reached, and the excavated material was hauled to points of use or waste disposal. To prevent shattering of the foundation rock, blasting was stopped from 1 to 2 feet above final excavation grades; and final preparation for concreting was performed principally with hand labor by breaking away all loose or questionable rock with paving breakers, sledges, wedges, and crowbars. A total of 332,800 cubic yards of rock was removed.

The depth of rock excavation varied considerably in different sections of the dam and greatly influenced the scheduling and progress of construction operations. Under the north nonoverflow section of the dam the top weathering was fairly uniform and about 8 feet deep. As this area was independent of river control operations, it was completed to allow concreting by May 31, 1942.

The depth of excavation varied from approximately 20 feet under the major portion of the intake to 35 feet near the spillway and under the powerhouse, although deeper excavation was necessary for the draft tubes. In the tailrace the depth of rock excavation was limited by the bottom slope of 7 to 1, which extended downstream and upward from the floor of the draft tube discharge openings to the natural river bed.

Rock excavation in the intake and powerhouse area was constricted until the river arm of the temporary dike was removed shortly after the first-stage river diversion. As the depth of excavation increased, water inflow through the many solution channels in the rock underneath the cofferdam made excavation difficult. Control of the inflow by means of cofferdam grouting, constant pumping, and the use of several small sandbag dikes was reasonably effective and helped prevent the leakage in the intake and powerhouse area from developing into the serious problem that it later became in the excavation for the spillway area.

Seven and one-half bays of the spillway section were enclosed within the first-stage cofferdam. Weathered rock extended over 40 feet deep in the major portion of this area, reaching an extreme depth of 60 feet at one point. This depth of excavation, combined with the large volume of water inflow through the innumerable solution channels under the cofferdam, made all excavation operations extremely hazardous and difficult.

Excavation for the spillway proceeded in essentially the same manner as in the intake section. At the upstream limits of excavation where the depth was generally greatest it was often necessary for the power shovels and hauling equipment to operate in water 2 feet or more in depth. Figure 86 shows the working conditions within the cofferdam area. Final hand excavation and clean-up prior to placing concrete were completed in the dry by enclosing individual small areas with temporary timber bulkheads and sandbag dikes, as shown in figure 87. The construction of the concreting trestle towers in this section was delayed until sound foundation rock was exposed, which in turn prevented spreading out concreting operations.

The remaining three and one-half bays of the spillway section were located within the second-stage cofferdam. The rock in this area was much better, and the depth of excavation averaged about 12 feet. The south end of the spillway was against a nearly vertical rock face blasted from the high rock bluff forming the left bank of the river.

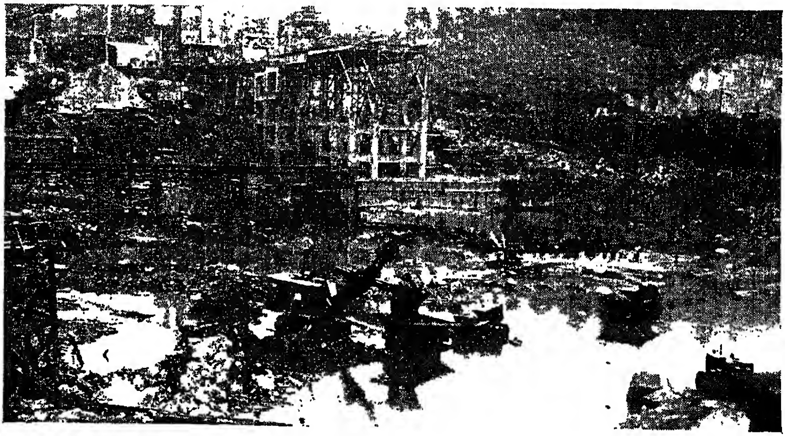


FIGURE 86.—*Conditions in cofferdam area.*

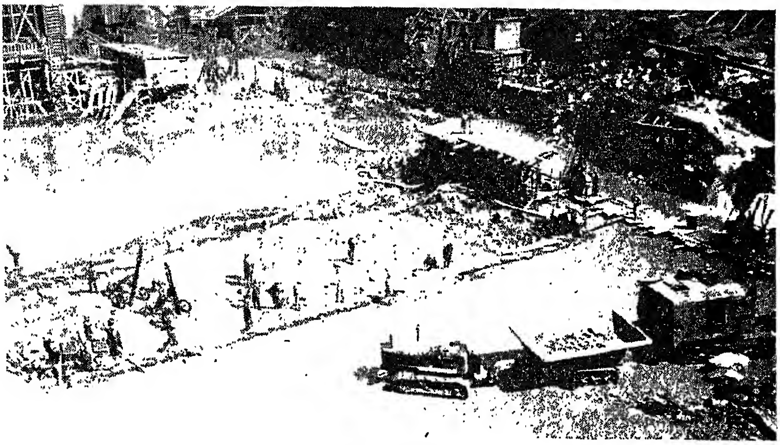


FIGURE 87.—*Preparing block for concreting.*

All the earth excavation and a large part of the rock excavation was completed during the construction of the first-stage diversion channel. During this time the rock face of the bluff was drilled and blasted from the top down to the river bed, and a portion of the diversion channel was excavated to approximate final grades. The rock adjacent to the first-stage cofferdam arm was not disturbed, to prevent possible sliding of the rock.

Following the construction and unwatering of the second-stage cofferdam, the remainder of the rock in this section of the spillway was removed. As there was practically no leakage, rapid progress was made and the excavation was completed in less than 3 weeks.

Rock removal in the south abutment area was independent of river control and was done concurrently with the excavation under other parts of the dam. Over most of the area the depth of excavation was approximately 50 feet, but it increased at the south end to 70 feet. It was carried to the solid bedding plane of dolomite previously described. Two strike joint solution channels were cleaned out by hand labor to elevation 833 and 863, respectively, and then filled with concrete.

Cavity excavation.—The cavity underlying the north abutment (fig. 83) covered a large portion of the area under the north end of the dam. It was cleaned out and backfilled with concrete before placing concrete above it.

A number of 42-inch shot drill holes were drilled from the rock surface to the roof of the cave on approximately 25-foot centers through which the hand-excavated muck was removed with air hoists. There was plenty of working room except near the south end where the height abruptly decreased to about 6 inches, necessitating enlargement of the cavity by light blasting.

Under the north end of the core wall extensive weathering of the rock existed above the roof of the cavity. It was necessary to excavate by open cut methods until the core wall could be extended to the floor of the cavity. A profile through the cavity is shown in figure 85.

Cleaning of the cavity under the south end of the dam was done concurrently with excavation in the south abutment area. The cavity was almost entirely filled with clay, which was removed by hand labor and hauled to the portal on a small car pulled by an air-operated winch over temporary tracks. At the south end of the cavity, where operation of the cable car to the portal was not feasible, the excavated material was brought to the surface in buckets through the 42-inch-diameter shot drill holes. At several points where the cavity narrowed sharply a small amount of rock was blasted out to provide adequate working room. As excavation progressed the roof was shored with 12- by 12-inch timbers. During the mining operations no difficulty was experienced with ground water above river level at elevation 873. Below this elevation periodic pumping was necessary.

To prevent leakage through the reservoir rim, a concrete cut-off wall or plug was designed and placed in the cavity as a water stop. The details of the bedding cavity are shown in figure 84.

FOUNDATION TREATMENT

The character of the foundation rock under the concrete dam and powerhouse presaged an extensive program of consolidation and curtain grouting to be closely coordinated with the other construction activities so that little or no delay would result. Between March 1942 and September 1943 a total of 317,436 cubic feet of cement and clay was injected into 168,866 linear feet of drill holes.

Consolidation grouting.—Under the concrete dam and powerhouse the foundation treatment included the consolidation of the foundation rock to a depth of 40 feet to prevent settlement. This was effected by drilling and grouting holes in stages with first-stage holes on 20-foot centers in rows parallel and perpendicular to the base line of the dam. Second-stage holes were drilled midway between the first-stage holes, with third-stage holes midway between second-stage holes. The drilling and grouting of one stage was completed before the next stage was started. The strict theoretical pattern of holes was varied where necessary to form a more economical grouting pattern in a particular area where numerous surface joint cracks appeared.

In general, wagon drills were used for drilling; but in some cases where the depth of hole exceeded 40 feet diamond core drills were used because of their greater economy. Practically all the holes were vertical, although in some places where known faulted solution channels existed some angle drilling was done to obtain the most effective coverage.

The drill holes and the seams intercepted by them were washed with air and water under pressure through nipples grouted into the holes at the rock surface. No attempt was made to wash or grout individual seams by the zone method with packers. Each hole, however, was water tested to determine the proper consistency of neat cement grout with which to start the grouting treatment.

Under the north nonoverflow section the consolidation holes were drilled through the concrete backfilled cave, and special care was taken to secure a tight seal between the concrete and the roof of the cavity.

To prevent the grout from traveling up and down stream into areas where it was not needed, the limit of the dam foundation was out-

lined with 40-foot-deep drill holes on 5-foot centers and grouted with a thick cement grout poured into the top of the holes.

A maximum pressure of 40 pounds per square inch, measured at the surface of the hole, was used for the consolidation grouting. In general, most of the grouting was completed prior to the placing of concrete in the base pours of the dam; but in some instances, to prevent delay of concreting operations, the pipe nipples were extended through the concrete and grouting was done between pours. Neat cement grout was used throughout, with the consistency varying from 0.6 to 2.0 parts of water to 1 part of portland cement.

Uplift gages for measuring any deformation of the foundation rock while consolidation grouting was in progress were installed as needed. These gages consisted of a rigid bar grouted in a hole about 10 feet deeper than the grout holes in the surrounding area. The rod extended approximately 6 inches above the foundation surface and terminated under a U-shaped bar or bridge which had its legs set firmly in the foundation rock. Any rock movement could then be measured in the gap between the end of the rod and the bridge.

Low-pressure curtain grouting.—To obtain a cut-off in the foundation underneath the dam, a grout curtain was injected in a line just downstream from and parallel to the upstream face of the dam. The holes, about 50 feet deep, were drilled with wagon and diamond drills; and the work was done in conjunction with the consolidation grouting.

The drilling and grouting were done in stages, with the first-stage holes on 24-foot centers. Additional stages depended on the grout consumption in preceding stages. At no point was the final spacing less than 12 feet; and at one point five stages were necessary, with a resulting spacing of 1.5 feet. Maximum grouting pressure was 40 pounds per square inch, measured at the top of the hole.

High-pressure curtain grouting.—To determine the depth of the high-pressure grout curtain, a number of deep test holes were drilled, water tested, and grouted. These tests indicated the necessity of a curtain with a maximum depth of 200 feet to cut off a number of small water-bearing seams encountered from 100 to 200 feet below the surface of the foundation.

The high-pressure curtain followed the line of the low-pressure grout curtain, and again the drilling and grouting were done in stages. The first-stage holes were placed on 18-foot centers; and successive stages reduced the hole spacing to a maximum of 9 feet and a minimum of 1.4 feet, depending on the grout consumption of preceding stages. The depth of drilling was decreased where the grout consumption of previously drilled holes indicated satisfactory grouting at lower levels, but the minimum depth of holes was maintained at 100 feet. All drilling was done with diamond-core drills.

A minimum of 30 feet of concrete was placed on the foundation rock before any high-pressure grouting was done. Since most of the drilling and grouting was done from the lower drainage gallery in the dam after a great deal of the concrete had been placed, additional protection was afforded against uplift when using the higher grouting pressures. The maximum grouting pressure used was 200 pounds per square inch, measured at the top of the hole. The grouting pressure in all cases was in excess of the hydrostatic pressure caused by the

reservoir head and less than the pressure of the overlying rock and concrete on the seam being grouted. Neat cement grout was used for all grouting and was proportioned volumetrically, with the mix varying from 0.6 to 5.0 parts of water to 1 part portland cement.

The zone method of grouting was used, the lowest seam in each hole being washed and grouted first. The packers were then raised, and after the grout had hardened the operation was repeated with each seam until all had been grouted.

Reservoir rim treatment.—To prevent percolation and possible leakage through the narrow portions of the reservoir rims adjacent to the dam, the grout curtain was extended into the rim from both the north and south ends of the concrete dam. On both the north and south rims the drilling and grouting were done in stages, with the first-stage holes on 100-foot centers and followed by as many stages as were necessary to check any area of high grout consumption. All the holes were drilled with diamond drills to elevation 860 or slightly lower than the elevation of the original river bed. No seam washing was attempted.

On the south rim the grout curtain extended for a distance of 700 feet from the south end of the dam. Extensive work was done here to check and tighten completely the area adjacent to the dam. This work also completely sealed the cave, which had been mined out and backfilled with a concrete plug. Five stages of grouting were required, resulting in a final hole spacing of 6.25 feet. Neat cement grout was used, varying from 0.6 to 2.0 parts of water to 1 part of portland cement by volume with 3 percent calcium chloride by weight of cement added to accelerate the setting time.

A check along the remainder of the south rim indicated that grouting was necessary only at saddle dam No. 1, where a grout curtain was provided for the complete length and considerable grout was injected, particularly at the contact between the Lenior limestone and the

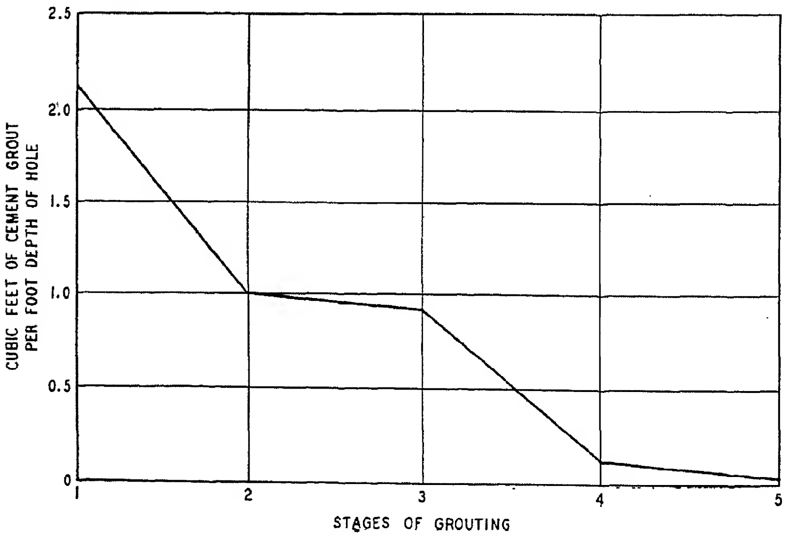


FIGURE 88.—*Grout consumption rate—dam.*

Athens shale. The grout consumption was confined chiefly to the Lenoir limestone since relatively few seams were found in the Athens shale.

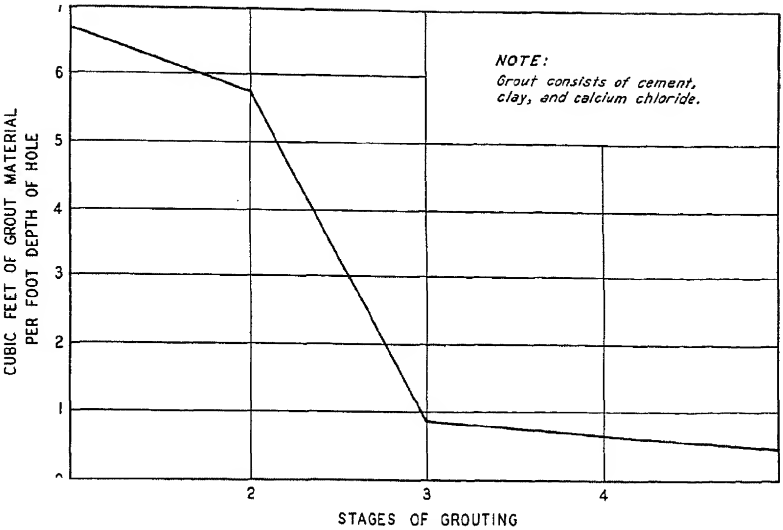


FIGURE 89.—*Grout consumption rate—south rim.*

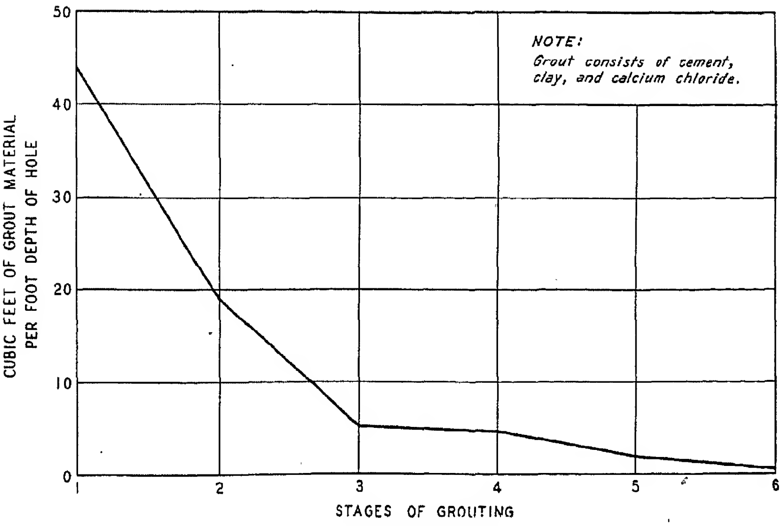


FIGURE 90.—*Grout consumption rate—north rim.*

The north reservoir rim adjacent to the north end of the concrete dam possessed some natural protection against seepage in the form of a flatly sloping earth blanket, but the great number of well-defined

dip cavities lying along the line of the grout curtain predicted a heavy grout consumption. It was neither necessary nor feasible to mine out and backfill these cavities with concrete, and in the interest of economy a low cost cement-clay grout mixture was tried in the proportion of 1 part of cement to 4½ parts of clay and 6 parts of water by volume. The slurry was pumped into the drill holes at low pressure, and large quantities were consumed. The maximum consumption per hole was 20,905 cubic feet, even though the pressures used were only slightly above gravity; and the consumption was limited to 500 cubic feet before suspending grouting and allowing the mixture to harden for a period of 3 days. The clay mixture was found to be spreading a great deal farther than was necessary for the formation of a grout curtain, and accordingly the cement-clay mixture was abandoned in favor of neat cement grout with calcium chloride added. In the north rim six successive stages of grouting were required, which reduced the final hole spacing to 3.12 feet. Drilling and grouting quantities for the entire foundation-preparation program are given in table 30.

TABLE 30.—*Foundation preparation quantities*

Item	Wagon drill holes	Diamond drill holes	Cement grout	Cement and clay
	Linear feet	*Linear feet*	*Cubic feet*	*Cubic feet*
Concrete dam:				
Consolidation	51,700	16,713	33,806	
Low-pressure curtain	8,160	13,164	9,702	
High-pressure curtain		39,380	51,340	
Reservoir rims:				
South rim		12,510	37,713	
Saddle dam No. 1		11,481	38,956	
North rim		15,758		[1] 145,919
Total	59,860	109,006	171,517	145,919

[1] Part of this was neat cement, part cement-clay grout.

DRAINAGE

A system of foundation drains was installed under the concrete dam to relieve any uplift pressure on the structure resulting from water, under reservoir pressure, seeping through the grout curtain. The relief system consisted of holes drilled from 10 to 40 feet into the foundation rock under the dam and provided with suitable collectors and outlets.

The main part of the system consists of a continuous line of 3½-inch holes on 8-foot centers drilled 40 feet into the foundation rock 23½ feet downstream from the base line throughout the entire length of the concrete structures. Twenty-four-inch half-round corrugated steel pipes in 22-foot sections, each covering 3 drill holes, were installed along the line to act as collectors. The holes were drilled from the inspection gallery after all grouting had been completed, some through 4-inch pipe sleeves set in the concrete and others through the concrete between the foundation rock and the gallery floor. The major portion of the holes were drilled directly from the floor of the drainage gallery without using pipes for a core barrel.

Another line of drill holes was placed 132.5 feet downstream from the base line through the spillway and intake sections of the structure. They were spaced 6 to 11 feet on centers and were drilled by 3½-inch diamond core drills approximately 20 feet into foundation rock. Eighteen-inch half-round vitrified clay pipe was used to collect the water from these holes. Eight-inch-diameter riser pipes were installed to discharge at the sides of the spillway sluices, and 12-inch cast-iron risers were installed at the ends of the collectors to discharge at the spillway face. Under the spillway apron relief holes were drilled to a depth of 10 feet in rock. They were spaced on 12-foot centers in a regular pattern along lines normal and parallel to the base line. A special drain outlet was provided at the top of each hole, consisting of a vertical 3-inch pipe with a coupling and plug placed flush with the concrete and a 1½-inch pipe connected to it at 45°, thus forming a Y, with the 1½-inch branch turned downstream and ground off flush with the concrete and left open for relief. The major portion of the holes in the apron were drilled through this drain outlet into foundation rock.

The floors of the draft tubes were relieved of uplift pressure through holes drilled into the foundation rock and extended through the concrete floor by 4-inch cast-iron riser pipes.

EARTH EMBANKMENTS

The reservoir rim extending southward from the end of the concrete dam included 10 low saddles. To impound the reservoir with suitable protection, saddle dams were required at eight of these points. The largest of these was saddle dam No. 1, located nearest the concrete dam. The others were relatively minor, and at two sites the water will probably never reach the dams except in case of a severe flood and high wave action.

The saddle dams were constructed entirely of rolled earth obtained from borrow pits located as near as possible to each site. The amount of fill placed in saddle dam No. 1 was 473,924 cubic yards. The second largest was No. 3, which contained 33,107 cubic yards; and the smallest dam was No. 4, which contained 439 cubic yards. The total amount of rolled fill placed in the eight saddle dams was 531,800 cubic yards.

Construction methods.—Two methods of earth moving were used. With a nearly level borrow pit and a long downgrade haul, elevating graders and fast moving Euclid bottom-dump trucks (fig. 91) were especially suited for hauling earth to saddle dam No. 1. For the other dams where the borrow pits were sloping, the length of haul short, and the quantity relatively small, the LeTourneau self-loading carry-all scrapers were used. The scrapers also stripped the vegetation from the dam sites and the borrow pits.

A LeTourneau rooter pulled by a Caterpillar D–8 tractor plowed the borrow pit area for the elevating graders (fig. 92). Road graders terraced the hillside to facilitate loading on level areas and maintained the hauling roads. This permitted loading operations to be carried on at high speed and with little equipment trouble.

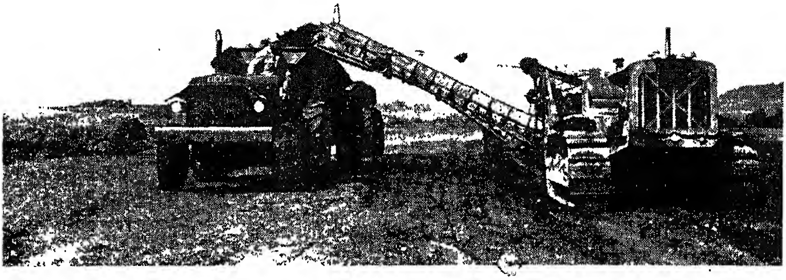


FIGURE 91.—*Loading clay for rolled fill.*

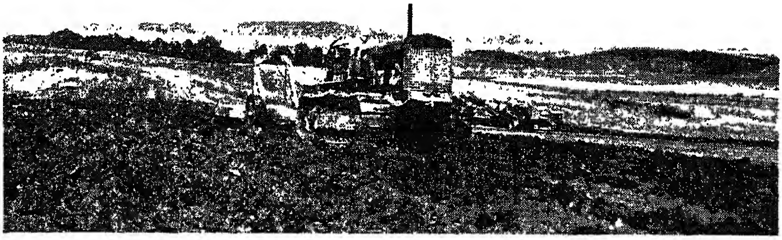


FIGURE 92.—*Plowing borrow pits for loading clay.*

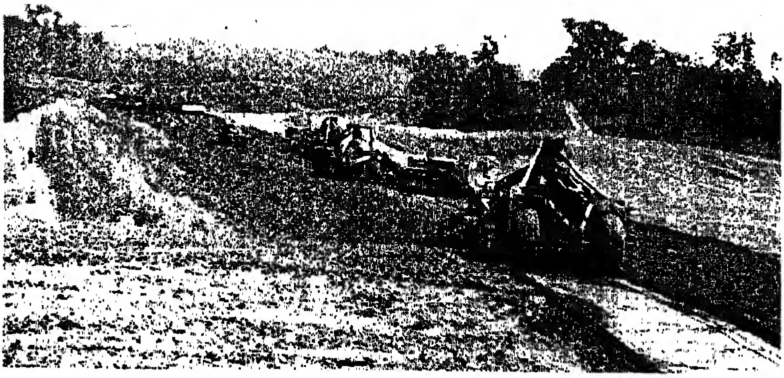


FIGURE 93.—*Placing clay for rolling.*

TABLE 31.—*Embankments—Rolled earth-fill cost*

[531,800 cubic yards]	*Cost per cubic yard, saddle dams*
Prepare borrow pits	$0.058
Load and haul:	
Labor	.014
Equipment operation	.266
Miscellaneous expense	.002
Spread and compact:	
Labor	.033
Equipment operation	.069
Miscellaneous expense	.012
Construction services and facilities	.056
Total cost, rolled fill	.510

After the earth had been dumped it was compacted with tandem tractor-drawn sheepsfoot rollers, so loaded as to give a pressure of 280 to 300 pounds per square inch of foot area. Bulldozer attachments on the tractors spread the windrows of material to a depth of 6 to 8 inches just ahead of the rollers (fig. 93). Ten passes of the

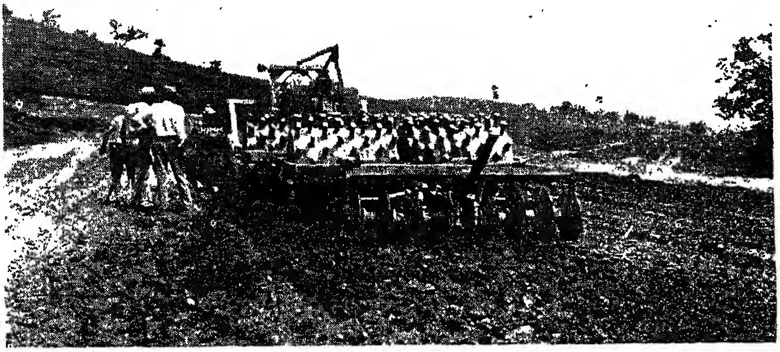


FIGURE 94.—*Rolling operations.*

two rollers usually gave the required compaction. A disk harrow attached to the rear sheepsfoot roller (fig. 94) scarified the surface after each pass, thus preventing the formation of smooth planes and voids. Hand-operated pneumatic tampers were used to secure compaction in places where the operation of the sheepsfoot rollers was not practicable. Rolled earth fill costs are given in table 31.

Drainage.—Saddle dams Nos. 1 and 3 were provided with 3-foot-thick crushed rock and sand drain blankets under the downstream third of the base areas. Eight-inch concrete drain laterals were embedded in the drain blankets with their outlets in a 12-inch concrete-pipe toe drain laid with open joints in a sand bed along the toe trench (see fig. 95).

The area downstream from saddle dam No. 1 required special drainage treatment. Before construction of the saddle dam the natural drainage was eastward to the French Broad River. After the dam had been built the eastward flow of this drainage was obstructed; and it was necessary to carry the drainage westward by collection ditches (fig. 96) and a 48-inch-diameter pipe, 1,550 feet long, and discharge

FIGURE 95.—*Toe drain for saddle dams.*

FIGURE 96.—*Drainage collection ditches.*

FIGURE 97.—*Riprap on upstream slopes of saddle dams.*

it into the river below the dam. The pipe was placed in a 194-foot tunnel under church property to avoid an open cut through a cemetery.

Slope protection.—The upstream slopes of the saddle dams were built on a 4.5 on 1 slope up to elevation 1000 and a 2.5 on 1 slope from elevation 1000 to the top. A 1-foot-thick blanket of crushed stone was placed on the rolled earth fill, and this was followed with a 3-foot-thick layer of riprap (fig. 97) quarried about 500 feet upstream from

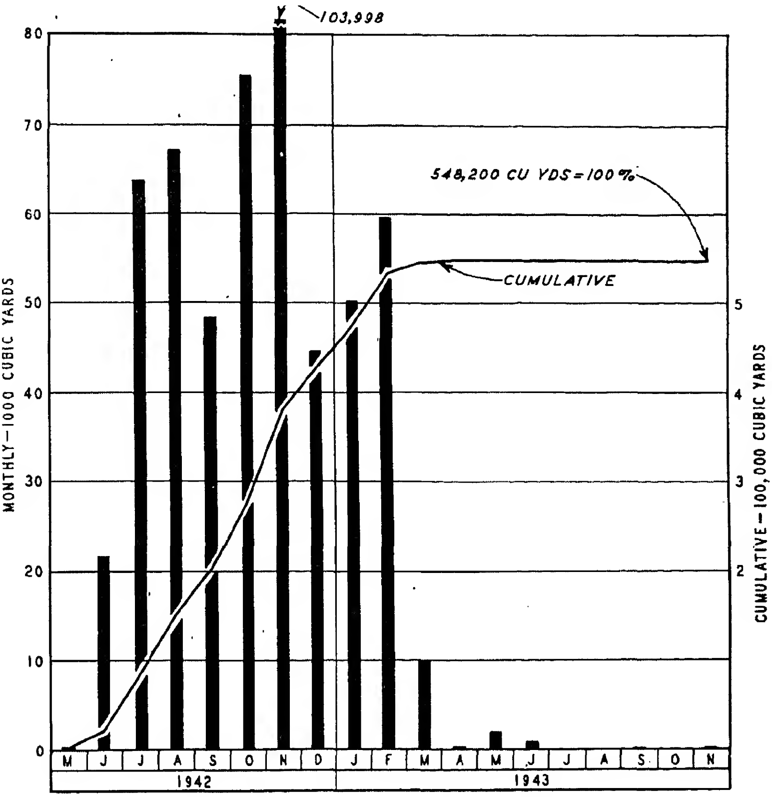


FIGURE 98.—*Monthly concrete quantities.*

the south end of the concrete dam and hauled to the site in dump trucks. A total of 44,843 cubic yards of rock riprap was placed on all the saddle dams.

The downstream slopes were covered with topsoil, liberally sprinkled with fertilizer, and sprigged with Bermuda grass.

CONCRETING

Concrete placing operations started May 31, 1942, only 4 months after the start of construction. The total mount of concrete placed

in the permanent structures at Douglas Dam was 548,200 cubic yards, 99 percent of which was placed by August 1, 1943. Concrete placing was on a fast schedule; and peak production was obtained during November 1942, when 103,998 cubic yards was placed. The concrete placed during the first 6 months amounted to 71 percent of the total. Maximum plant capacity could not be maintained because of the difficult excavation which retarded the preparation of foundations and the extension of the construction trestle.

Materials

Cement.—A modified type B portland cement was used for most of the concrete although, because of War Production Board limitations, the mills were unable to supply enough type B and it was necessary to use small quantities of types 1 and 2. The type 1 corresponds to standard portland cement, and the type 2 is very similar to the type B.

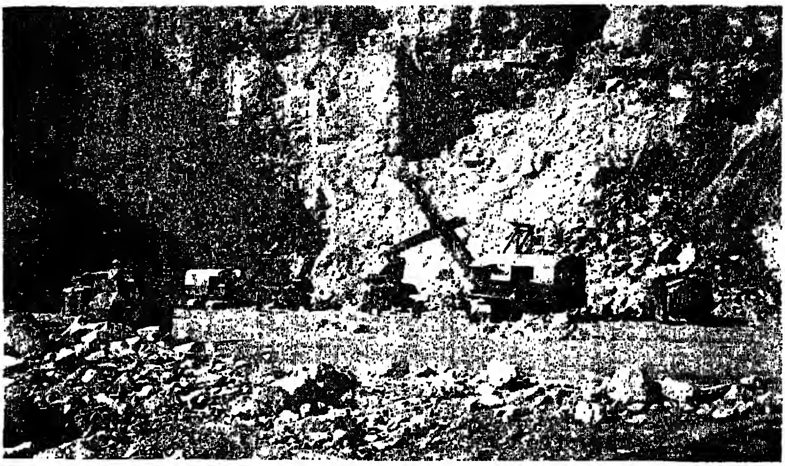


FIGURE 99.—*Aggregate quarry.*

Aggregates.—Suitable rock for both coarse and fine aggregate was found in a high rock bluff located on the north side of the river approximately 2,000 feet downstream from the dam. The rock was dolomite of the Knox formation and was identical to that used for concrete aggregate for the construction of Norris Dam. The land including the quarry site was purchased by TVA, and a contract was awarded the Birmingham Slag Co. for furnishing approximately 700,000 tons of crushed stone and 300,000 tons of manufactured sand.

In addition to furnishing aggregate for concrete, the contractor furnished about 24,000 cubic yards of crushed rock for the cushion under the riprap on the embankments. Figure 99 shows the aggregate quarry.

Design of concrete mixes

Maximum water-cement ratios of 0.55 and 0.75 by weight were chosen respectively for the exposed and unexposed concrete while a ratio of 0.50 was used for grout. In some cases, however, field con-

ditions required a change in the water-cement ratio. The cement content was determined by the workability of the mix and the water-cement ratio.

Mixes were designed using four sizes of aggregate ranging from the 6-inch cobble to that retained on a No. 4 screen; material passing the No. 4 screen was designated as sand. To fit all conditions, mixes were designed with maximum sizes of aggregate of 6, 3, and 1½ inches and ¾ inch. Placing conditions, such as the size of the form, spacing of reinforcing, method of placing and vibrating, and the design specifications for strength and durability, determined the selection of the proper mix. Gravel-sand ratios, determined by trial, varied from 2.7 for the 6-inch mixes to 1.8 for the 1½-inch mixes. The "straight line" method was used to determine the gradation of the aggregates, although considerable adjustment was required in combining the various sizes during the mixing operation to take care of the variation in the aggregate, especially that caused by the excess of "fines" and undersize material.

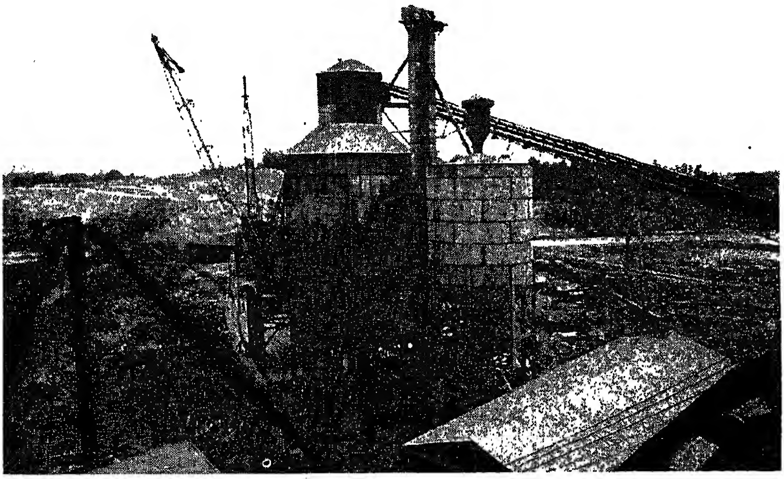


FIGURE 100.—*Mixing plant.*

All the concrete in the permanent structures was divided into two general types or classifications: exposed or face concrete, and unexposed or interior mass concrete. Six basic mixes were designed to fit these types of concrete. For concrete having a maximum-size aggregate of 6 inches, a minimum cement content per cubic yard of 0.85 barrel of cement for interior mass concrete and 1.15 barrels of cement for exterior face concrete was selected. In general, with these cement contents the desired "workability" could be obtained by using maximum water-cement ratios of 0.75 and 0.55, respectively. These two mixes represented about 70 percent of all the concrete placed. Until the workmen became used to the stiff concrete and the proper vibrating methods, a 6-inch mass mix with 0.90 barrel of cement per cubic yard and a water-cement ratio of 0.67 was adopted. Some special mixes were used in placing the closure concrete.

TABLE 32.—*Basic mixes—weights of*

Mix identification	Location used	Maximum-size aggregate, inches	Cement content, barrels per cubic yard	Water-cement ratio by weight
6-inch—0.85-0.75	Interior nonreinforced mass	6	0.85	0.75
6-inch—1.15-0.55	Exterior nonreinforced face	6	1.15	.55
3-inch—1.05-0.75	Interior reinforced areas	3	1.05	.75
3-inch—1.30-0.55	Exterior reinforced areas	3	1.30	.55
1½-inch—1.55-0.55	Heavy reinforced areas	1½	1.55	.55
¾-inch—1.83-0.55	Very heavy reinforced areas	¾	1.83	.55
¼-inch—2.75-0.50	Grouting	¼	2.75	.50

Table 32 gives the basic mixes, including the weights of materials per batch and the batch yield.

Control of concrete mixes

Materials testing.—Routine laboratory tests made on the job were confined to tests of aggregate and concrete, while standard chemical and physical tests of cement were made at the various mills prior to shipment. An inspector was stationed at each of the mills during the time cement was being manufactured or shipped to the project. A laboratory was maintained at the aggregate plant, and inspectors made all necessary tests to determine whether specifications were being met. These tests included sieve analysis, specific gravity, unit weight, absorption, and free moisture content.

A small laboratory in the mixer building was operated by an inspector, who took samples of the aggregate for sieve analysis, specific gravity, unit weight, moisture, and absorption tests. Only the moisture and absorption tests were made in this laboratory, the other tests being made in the main field laboratory. Aggregate samples were taken approximately every 45 minutes, and moisture tests were made to determine the amount of free moisture. The additional weight of water required to give the proper water-cement ratio was then computed.

The workability of the concrete was affected by the changes in aggregate gradation. These changes were often of short duration and were caused by local disturbances in the stock piles. In such cases where a sieve analysis could not be made in time, the changes were compensated for by the plant inspector's making the necessary increase or decrease in the quantities of the various sizes after a visual inspection of the aggregate.

One sample of mixed concrete was taken by the inspectors on each shift, from which four or six standard 6- by 12-inch compression test cylinders were made. The results of the 7-day tests on these cylinders (table 33) served as a check on the mix design. Other tests were made in 28 days.

materials per batch and batch yield

Weights of materials—pounds (aggregate surface-dry)							Batch yield, cubic yards
Water	Cement	Sand	Stone				
			No. 4—¾-inch	¾-1½-inch	1½-3-inch	3-6-inch	
1,007	1,342	4,427	2,214	2,214	3,004	3,953	4.20
999	1,816	4,471	2,158	2,158	2,930	3,700	4.20
1,244	1,658	4,610	3,271	2,825	4,164	----	4.20
1,129	2,053	4,602	3,266	2,820	4,156	----	4.20
1,346	2,448	5,000	4,306	4,583	----	----	4.20
1,137	2,068	4,719	4,429	----	----	----	3.00
1,034	2,068	4,719	----	----	----	----	2.00

TABLE 33.—*Compression tests*

Mix	Age, days	Number of cylinders	Average water-cement ratio by weight	Average crushing strength, pounds per square inch
6-0.80-0.75	3	31	0.76	1,711
	5	2	.77	2,299
	7	146	.75	2,418
	28	110	.75	3,511
6-0.85-0.75	7	163	.72	2,398
	28	170	.73	3,683
6-0.90-0.75	7	142	.69	2,574
	28	129	.69	3,843
6-1.10-0.55	3	8	.59	2,127
	5	6	.59	3,122
	7	76	.57	3,583
	28	69	.57	5,040
6-1.15-0.55	7	119	.55	3,993
	28	117	.55	5,653
6-1.20-0.55	7	10	.53	4,376
	28	10	.53	6,270
3-1.05-0.75	3	2	.67	2,149
	7	121	.72	2,544
	28	117	.72	3,836
3-1.10-0.75	7	4	.67	2,348
	28	4	.67	3,657
3-1.30-0.55	3	2	.55	2,759
	7	157	.55	3,613
	28	24	.55	5,139
1½-1.50-0.55	7	32	.55	3,774
	28	25	.56	5,227
1½-1.55-0.55	7	202	.54	3,496
	28	195	.57	5,377
1½-1.60-0.55	7	8	.54	3,725
	28	8	.54	5,392
¾-1.83-0.55	7	15	.55	3,325
	28	9	.55	5,119

Concrete mixing

The main concrete mixing plant (fig. 100) was the same equipment that had been used at Cherokee Dam. It was entirely automatic; and all operations, which included the batching, charging, and mixing, were controlled by an automatic push button system located in the mixer building and operated by one man. The lights and signal devices informed the operator of the position of the charging chute, when a mixer was fully charged, when the time allowed for mixing was up, and when a concrete bucket was under the plant ready to receive material from a mixer. He was also notified by lights of an excess or deficiency of the material in the batching scales. From the control station the operator had a view of [illegible] operations and could see the mixers and discharge chute.

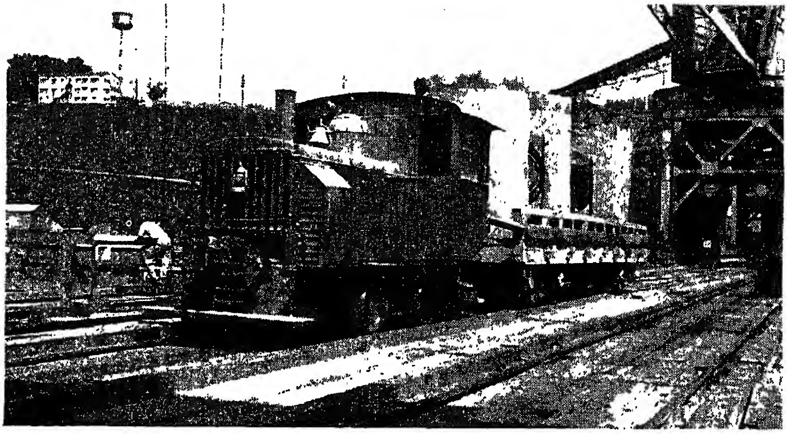


FIGURE 101.—*Concrete train.*

The mixing plant was designed to produce approximately 240 cubic yards of concrete an hour, based on a 3-minute cycle of operation and 4.0-cubic-yard batches. It was found that the cycle of operation could be reduced to 2 minutes and 55 seconds and, at the same time, the mixers could be operated with a 5 percent overload or with batches of 4.2 cubic yards. This made the maximum theoretical production 259 cubic yards per hour. Batches of 4.4 cubic yards were tried, but the spillage was excessive.

The mixing cycle of 2 minutes and 55 seconds was divided as follows:

	Minutes	*Seconds*
Charge mixers	0	10
Mixing time	2	30
Dump and right mixers	0	15
Total	2	55

The weighing time, which was about 15 seconds, did not affect production since an interval of about 48 seconds was available for that operation.

Dispatching and transporting

Because of the concentration of operations on the construction trestle, a dispatching system of lights and buzzers was used to route the proper mix of concrete to its correct location without loss of time and without confusion. The system was operated from a control panel in the mixer building. The dispatcher had telephone connections with the trestle foreman and the placing inspector in the form.

Concrete was discharged from the mixers into 4.2-cubic-yard buckets carried on railroad flat cars which ran beneath the discharge spout of the mixing plant. One to five trains, each consisting of a locomotive and one flatcar (fig. 101) carrying three full buckets with

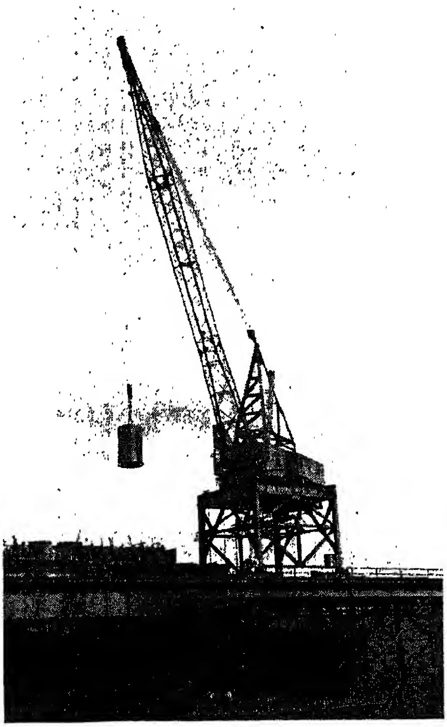


FIGURE 102.—*Placing concrete.*

one empty stall, were operated at any one time. The buckets were hauled across the construction trestle to one of the four gantry cranes which swung them into the forms (fig. 102). Each bucket was tagged with the type of concrete, such as mass, face, or grout.

Concrete placing

Where time permitted, concrete was placed in the mass structures in 5-foot lifts with a 72-hour cooling interval between lifts. The general concreting schedule was made to fit this rate; but because of the difficulty in uncovering foundations and extending the construction

trestle, it was necessary to increase this rate in certain parts of the dam. Where the rate of placement was increased in this manner, a system of artificial cooling was required.

Special attention was given to bonding the concrete at the horizontal construction joints. After the surface of the previous pour had been cut and washed (see p. 224) grout was brushed into it with wire brooms, keeping it just ahead of the mass concrete, which was usually started near the upstream end of the block to keep the men from under the bucket. A windrow of interior mass concrete was placed across the block about 5 feet downstream from the end form. Face concrete was then placed between the windrow and the form, and the layer of mass concrete continued down the block. A 5-foot lift was usually placed in four layers, with each layer kept just ahead of the one above it. Approximately 5 feet of face concrete was placed next to the form on the downstream end of the block.

The concrete was compacted with vibrators. In the mass pours two-man spade-type internal electric vibrators operating on 90-cycle current were used. For the small heavily reinforced pours flexible-shaft vibrators were employed. The number of vibrators necessary varied with the size of the pour, rate of placing, type of concrete, and placing conditions; but in the main blocks four were usually required. When the concrete was placed in four layers (15 inches deep after vibrating), four vibrators could handle from 80 to 100 cubic yards of concrete an hour.

One placing crew and a crane were generally assigned to each pour. During peak production periods there were three such crews placing concrete in three different blocks of the main dam, while a fourth crane was placing small pours of the powerhouse and training walls. When a particular pour had to be placed more rapidly two cranes and two placing crews were assigned to it, which increased the rate of placement approximately 70 percent. The average rate of placement per crane-hour was 80 cubic yards.

The downstream portion of the spillway training walls, spillway apron, and the tailrace wall were beyond the reach of the gantry cranes operating from the construction trestle. To place concrete in these locations, a 4-cubic-yard hopper was located on the apron directly below the downstream edge of the construction trestle, and concrete was fed to the hopper through a flexible steel pipe or "elephant's trunk" extending from the trestle. A special train consisting of a Diesel locomotive and a flatcar carrying two 4-cubic-yard hoppers hauled concrete from the mixing plant and dumped it directly into the "elephant's trunk." Trucks carrying 2-cubic-yard buckets transported the concrete to crawler cranes which swung the buckets into the form.

Since the construction trestle did not extend north far enough to allow the gantry cranes to place concrete in blocks 1 to 4, inclusive, and the north core wall, a stiffleg derrick was erected just downstream from block 2 to handle the 4-cubic-yard buckets from the concrete trains. The core wall was poured with transit mix trucks from a small batching plant.

Artificial cooling.—To speed up concrete placing in most of the main dam, the heat of hydration was dissipated by artificial cooling. This permitted reducing the time interval between pours to 48 hours.

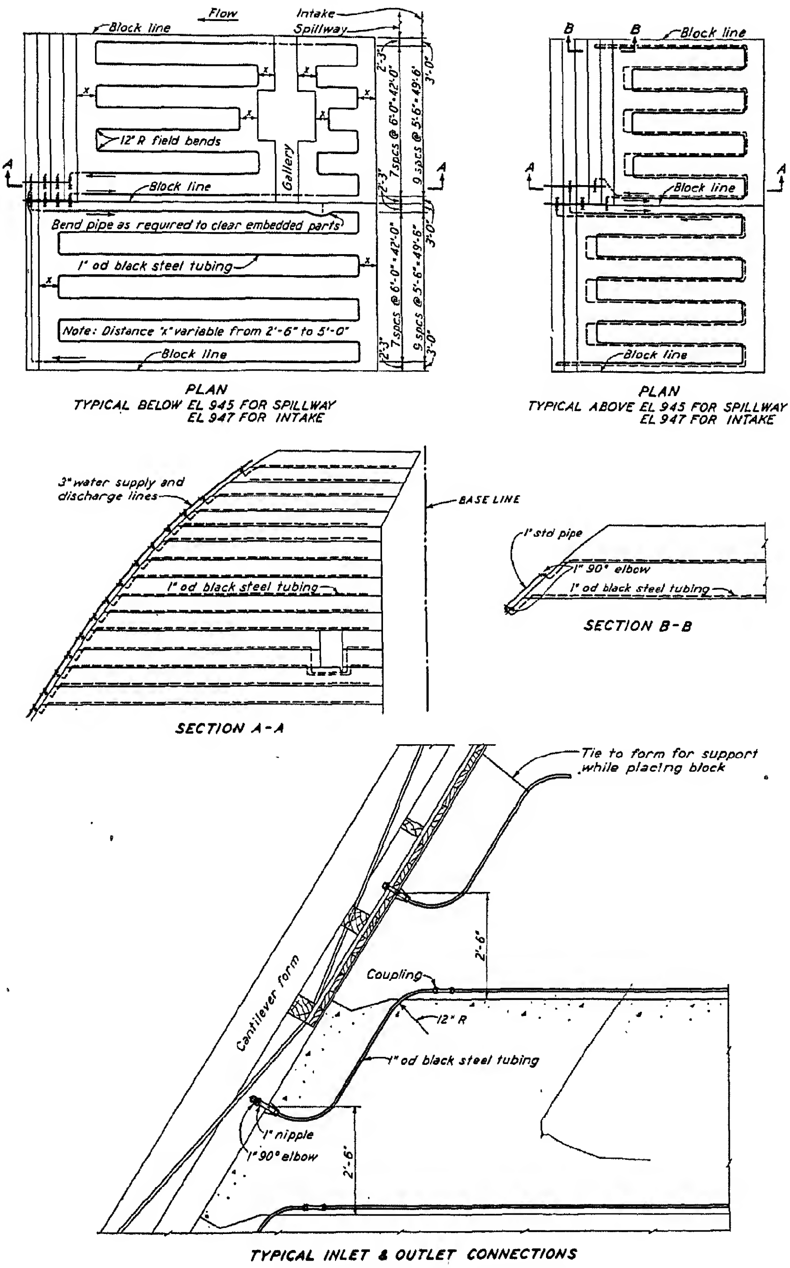


FIGURE 103.—*Concrete dam cooling system.*

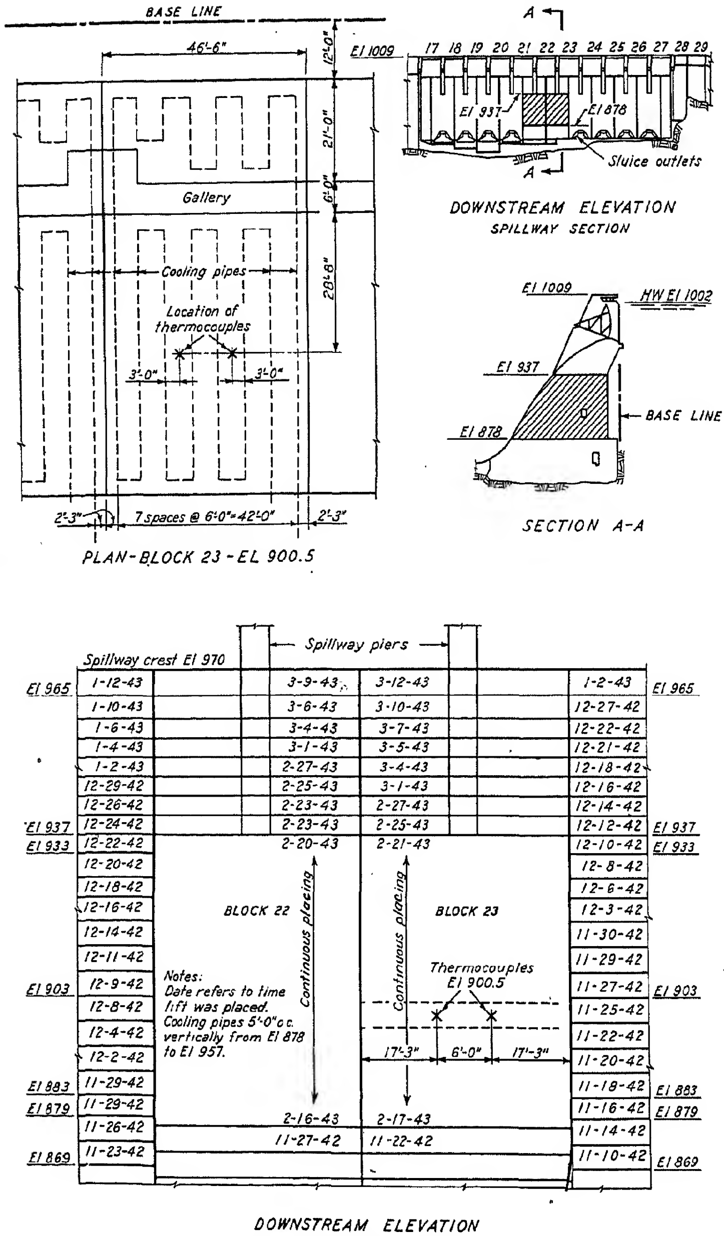


FIGURE 104.—*Arrangement of placements in closure blocks.*

The cooling pipes were made of 1-inch round thin-walled tubing and laid in loops on 6-foot centers directly on the surface of the previous lift. The loops were made up by bending the pipe without the use of fittings, and special fittings were used to make the connection at the form. The maximum length of pipe for any one course was set at 1,200 feet, and the minimum length at 400 feet. A pipe header was carried up the downstream face of the dam to feed the coils in the block. River water was pumped through each coil at the theoretical rate of 5 gallons per minute. Later the pipe headers were removed, and the cooling coils were blown out and filled with neat cement grout. Figure 103 shows the arrangement of the cooling water piping in the main dam.

Closure concrete.—The stream diversion opening in blocks 22 and 23 above elevation 878 was ready for closing in February 1943, just ahead of the season of heavy rainfall. Standard concrete-placing methods would have delayed the closure so that the spring rains could not have been impounded for power production in March. Therefore, to close the two spillway blocks as rapidly as possible, the concrete was placed continuously from elevation 878 to elevation 937 although it was recognized that continuous placing was unique on large dams. Above elevation 937 it was placed in 4-foot lifts with at least 72 hours between lifts.

Cooling pipes were installed at each 5-foot interval of height, and water was turned on about 12 hours after the pipes were covered. The 12-hour interval permitted initial set of the concrete to take place without delay and provided sufficient early strength for form stripping and raising. Figure 104 gives data and shows the arrangement of concrete pours in the closure blocks and in the adjacent blocks 21 and 24.

To obtain the temperature of the interior of the blocks, thermocouples were installed in block 23. This block was selected because it was the follow block and would probably have a greater temperature rise than block 22 (see fig. 105). The water discharging from the cooling pipes was allowed to run down the face of the blocks for curing purposes. Thermometers were set in the downstream face about 2 inches in from the surface to obtain a check of the temperature of the face concrete. The air temperature during the period of continuous placing varied from 13° to 68° Fahrenheit, and the concrete-placing

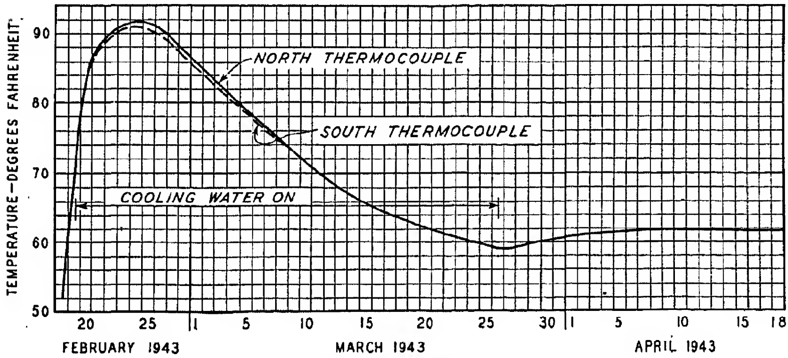


FIGURE 105.—***Cooling curve.***

temperature ranged from 40° to 66° Fahrenheit. Records of temperature rise and compression tests made on some core samples indicated that excellent concrete was obtained (see table 33).

Horizontal construction joints

The green-cut method of horizontal construction joint treatment was used for the entire job. This method insures an almost perfect bond between the pours. Test cores drilled through the joint showed that in most cases it was impossible visually to identify the joint, and when the core was tested in tension or compression failure did not occur at the joint.

The method consists of cutting off a layer of the green surface not over ¼-inch thick with an air and water jet applied at a pressure of approximately 100 pounds per square inch. This removes loose sand, dirt, and laitance, and exposes the aggregate. The surface is then left until just prior to concrete pouring, at which time it is thoroughly washed.

The success of the treatment depends upon the time the first cutting is started. If it is started too early, the jet cuts too deep and loosens the coarse aggregate; if too late, the concrete is too hard. The time of starting varies from 6 to 24 hours after finishing the pour and depends on the temperature of the concrete, temperature and humidity of the air, kind of cement, amount of cement, water gain, and traffic on the surface. In general, the colder the weather the longer the cutting is delayed. Experienced workmen can tell about when to start from the appearance of the surface.

Curing

Membrane curing was used for all exposed concrete surfaces except the horizontal construction joints and the powerhouse interior, where water was used. The membrane compound was Aquastatic Clear, to which a red fugitive dye was added that disappeared after 5 to 7 days' exposure. The color showed the portions that had been covered.

The compound was applied with small sprays at the rate of about 1 gallon per 300 square feet as soon as the forms were stripped and before the surface of the concrete had dried. This was usually about 24 hours after the concrete had been placed. Surfaces which had dried were wet down and the free water allowed to soak in or evaporate before the compound was applied.

Freshly placed concrete walls and ceilings in the powerhouse were kept moist, and a blanket of moist sand was kept on the floors.

Winter protection

The cold weather periods were not severe, and only a small amount of protection was needed to prevent the concrete from freezing. Ample protection was provided by erecting canvas windbreakers and placing charcoal salamanders in the blocks. Water at the mixing plant was heated during cold weather, and steam was circulated through the aggregate bins.

FORMWORK

Concrete construction required a total of 1,253,000 square feet of form contact area. Of this amount, cantilever panels were used to form 378,380 square feet of contact surface in mass concrete and 38,423 square feet of contact area in walls and piers. The powerhouse

substructure, superstructure, spillway apron, tailrace wall, and intake trashrack were placed with other types of forms. Although the panel forms used on other TVA projects had been satisfactory, the shortage of critical material and manpower indicated the necessity of using a type of form which would save as much material and labor as possible. A cantilever type which eliminated the metal tie-backs at the top of the panel seemed to fulfill these requirements. Table 34 gives a summary of formwork areas and costs.

Cantilever panel forms

Requirements for adoption.—The cantilever panel forms had to fulfill the following requirements:

1. The elimination of as much steel as possible.
2. The elimination of as much fabricating shop time as possible.
3. A simple design with the elimination of as many working parts as possible.
4. Provision for easy and quick alinement and stripping.
5. Low costs.

Design.—The forms were designed for a 5-foot lift of fluid concrete weighing 150 pounds per cubic foot. The details of the final design are shown in figures 106 and 107. The upstream, downstream, and bulkhead panels were 27 feet 9 inches long for an intake block and 23 feet 3 inches long for a spillway or nonoverflow block. Two of these panels formed the full width of the block. Shorter panels were made up for the bulkheads so that as the blocks decreased in length the panels could be more easily taken out.

TABLE 34.—*Formwork areas and costs*

AVERAGE COSTS AND RATIOS

Item	Powerhouse substructure	Powerhouse superstructure	Intake	Spillway mass	Spillway pier and tailrace wall	Spillway apron
Concrete ....cubic yards..	35,692	5,863	949	451,829	8,256	35,505
Formwork........square feet..	148,876	81,166	17,471	865,728	55,207	65,261
Cost per square foot, erect and strip........	$1.98	$2.14	$2.41	$1.19	$1.20	$1.28
Ratio of types, percent:						
Panels........	23	....	....	44	69	....
Other........	77	100	100	56	31	100
Square foot contact per cubic yard of concrete........	4.17	13.84	18.41	1.92	6.70	1.84

PANEL FORMS

[23,010 square feet contact area]

Item	Cost per square foot
Panel form fabrication, cantilever panels:	
Labor........	$1.022
Material and expense........	1.244
Total cantilever panels........	2.266
Repairs:	
Labor........	.062
Miscellaneous material and expense........	.019
Total repairs........	.081
Transport:	
Labor........	.100
Equipment operation........	.240
Total transport........	.340
Total cost of forms........	.687

Number of panels built, 212; total contact area, 23,010 square feet; lumber used, 227,474 feet board measure; 9.89 feet board measure per square foot contact area; average use of panels, 19.65 times; formed by panels, 452,238 square feet contact area; panel cost per square foot of contact area formed, $0.139.

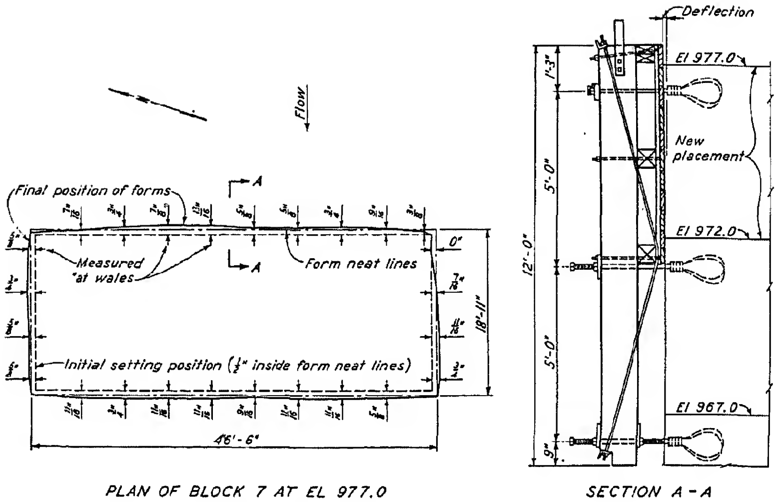


FIGURE 106.—*Deflections of forms.*

Material.—Lumber could not be purchased in sufficient quantities to fabricate the panel forms in time for use, so it was necessary to use the timber that was cleared from the reservoir for all but the tongue-and-groove sheathing. The logs were hauled to the job site and sawed to size by a portable sawmill. The lumber was unseasoned and not properly graded but served fairly well for rough construction uses. Machine shop time was saved by the purchase of patented anchor ty-loops and lag bolts.

Usage.—The panels were set on the base pours of the blocks by the gantry cranes, and a safety scaffold was attached. After they had been erected around the block, they were adjusted with the lower anchor bolt so that the top was set in ½ inch to allow for the deflection of the form caused by the concrete load. The forms were stripped and raised with chain hoists suspended from light-weight aluminum A-frames.

The cantilever panels were reused many times; in some cases 40 reuses were recorded. After a panel had been placed on the block it usually remained in its place until the top of the block was reached, although some of the downstream bulkhead panels were dropped off as the block narrowed.

Other forms

Panel forms were used on only one-third of the formed surfaces. The other two-thirds were formed with various types, including built-in-place forms and forms built in the shop for special use. Included in the latter category were those for the draft tubes, gallery, and turbine pit.

Blocks 22 and 23 were the closure blocks and were poured continuously for a height of 50 feet with block 22 leading. The contraction joint between these two blocks was maintained during the fast rate of pouring by a special bulkhead panel, the details of which

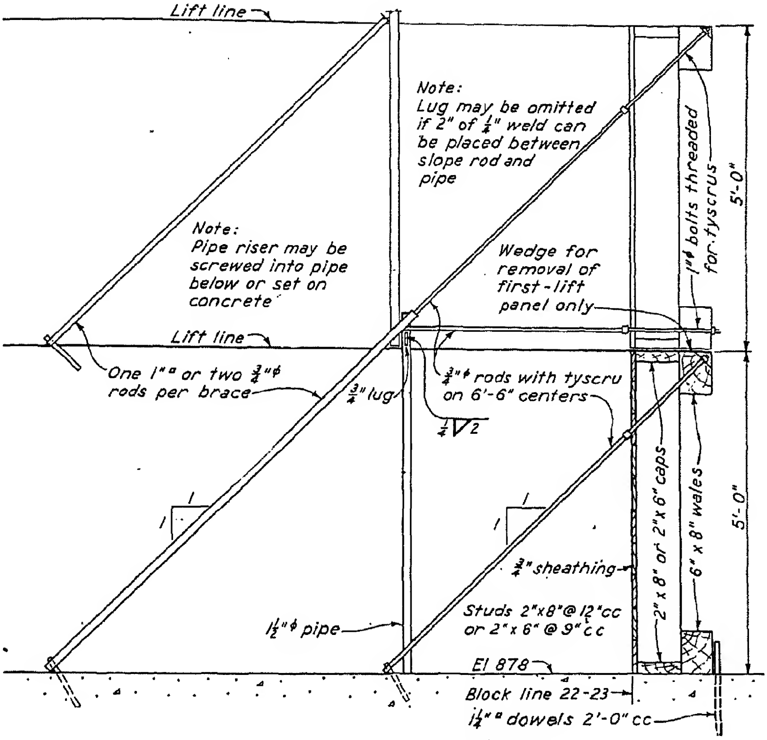


FIGURE 107.—*Closure panel forms.*

are shown in figure 107. The panels were made in 5-foot vertical heights; and by using two panels, alternating one on top of the other for each successive 5 feet of pouring, it was always possible to have a form in place.

Absorptive form lining.—Absorptive form lining was used to line the forms on the downstream or overflow surface of the spillway section of the dam. This wood pulp product absorbed the free water in the concrete near the form while the concrete was still in a plastic condition, thereby tending to lower the water-cement ratio and produce a "case hardening" effect on the surface concrete; and the appearance of the concrete was also improved.

The lining was used on the exterior walls of the powerhouse for architectural purposes. When the rough side was placed next to the concrete the resultant texture had the appearance of limestone or granite. Extreme care was required to prevent damage to the form lining while making the thin-walled heavily reinforced pours. This practice allowed the exterior walls of the control building to be made of poured-in-place concrete instead of precast blocks or limestone.

SPILLWAY

The spillway section of the dam includes blocks 17 to 28 and the downstream apron. The piers in the center of blocks 18 to 27, in-

clusive, and the training walls in the center of blocks 17 and 28 form the 11 overflow bays. Closure was made February 19, 1943, piers were completed March 22, and gates and bridge were in place by the end of April.

Reinforcing steel

Approximately 2,100 tons of reinforcing steel was used in the construction of the spillway section, most of which was placed in the apron. The steel was chiefly intermediate grade new billet steel; but because of the steel shortage, hard-grade bars were used in locations where the substitution could be made satisfactorily, usually where no bending was required.

The bars were unloaded by locomotive crane and stored in the yard according to length and size. After removal from the storage piles, they were cut to length with an acetylene torch and then shaped by a bending machine.

Spillway sluices

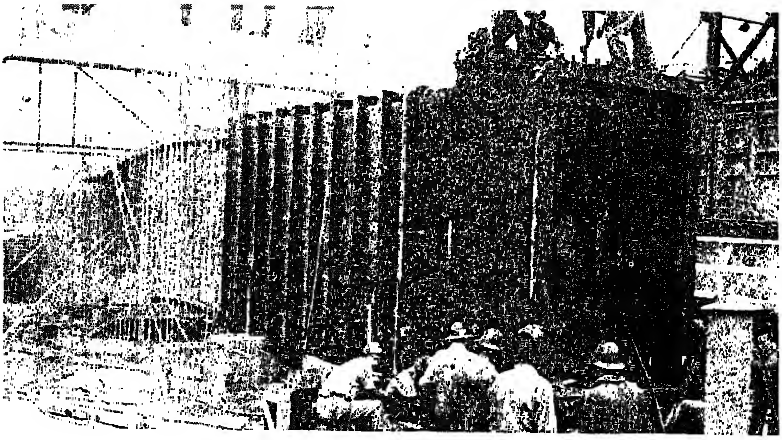
Eight steel-lined sluices (fig. 108) were installed in the base of the spillway section for discharging water during low stages of the reservoir and for additional spillway capacity. Two hydraulically operated slide gates were installed in each sluice, one for regular operation, the other for emergency use. The gates are operated from a room adjacent to the inspection gallery.

Sluices 1 to 5, inclusive, in blocks 18, 19, 20, 21, and 24 were constructed in the first-stage cofferdam; and sluices 6 to 8, inclusive, in blocks 25, 26, and 27 were installed as a part of the second-stage construction. All the sluices were used to bypass the river during final closure operations.

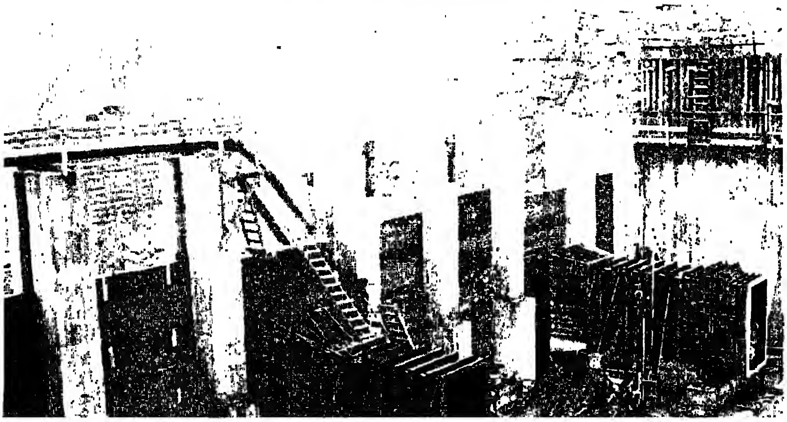
Sluice liners.—Each sluice is approximately 114 feet in length and is lined with ¾-inch steel plate for a distance of about 50 feet from the upstream face of the dam. The sluices are 5 feet 8 inches wide by 10 feet high, with a flared opening at the upper end formed by a steel casting with an opening 12 feet 6 inches high by 8 feet 2 inches wide. The discharge of the sluice was made through a flared concrete outlet directly to the spillway apron and stilling pool.

Slide gates.—Sixteen slide gates and frames were fabricated under contract and shipped to the job for operating the sluices. The embedded parts of the twin gate assemblies, such as the gate frame and bonnet castings, were received from the manufacturer and installed in each of the eight conduits. Delivery of the complete gate assemblies was not made in time for erection; and to avoid delay, the downstream gate leaves and gate-operating cylinder assemblies were transferred from Cherokee Dam to be placed in the upstream position at Douglas Dam for initial operation. Eight cylinder assemblies, five gate leaves, and five bonnet caps were delivered from the manufacturer in time for installation. Temporary steel cover plates were bolted to the tops of downstream gate bonnets at both Cherokee and Douglas to replace the cylinder assemblies. Upon final delivery of all gate assemblies, the parts were distributed at Cherokee and Douglas Dams to complete the installation at both projects.

Liner and gate assembly installation.—The unlined sections were formed in the concrete up to elevation 873, where concreting operations were stopped and small concrete footings were formed to support the gate castings and adjacent steel liner sections (see fig. 108).



a. Sluice liner erection and forms.



b. Sluice liner erection—blocks 26 and 27. Temporary bulkhead protects working area against high flows.

FIGURE 108.—*Installing sluice liners and forms.*

In sluices 1 to 5 the gate frames were first set and adjusted in position by means of steel shims, then secured with anchor bolts in the concrete footings. The remaining sections of the liner, including the bell-mouth intake, were bolted to the frames and adjusted with steel shims to correct elevation. The assembled liner was braced with steel tie rods welded to the top of the liner and to projecting steel dowels in the concrete, and the remaining sections of wood forms were placed. The bonnets were then bolted to the gate frames, the upstream gate leaves were installed, and concreting was resumed.

In sluices 6 to 8 the installation sequence was influenced by the presence of the auxiliary cofferdam bulkhead at the upstream face

of the dam and by the accelerated concrete-pouring schedule. The bulkhead piers were located between the sluice intake openings, and immediately after their construction was completed the bell-mouth intake casting and the remaining sluiceway sections were subsequently alined to these piers. Support for the casting was provided by a small concrete footing in the center, a welded angle iron frame at the upstream end, and a 3-inch pipe frame with screw jacks for adjustment at the downstream end. Construction of the downstream unlined section of the conduit proceeded concurrently; when concreting reached elevation 873 the gate castings and remaining liner sections were installed as in stage-1 construction. The inside surface of the sluice liners was sandblasted and covered with three applications of cold bitumastic paint.

After the upstream gate leaf had been placed in the guides the bonnet cap was bolted in place, and the piston shaft was inserted through the bonnet cap bearing and coupled to the gate leaf. The cylinder was then lowered over the piston and bolted to the bonnet cap, completing the hoist assembly. Installation of the hydraulic oil pressure system for gate operation followed, but prior to its completion the gates were operated by a temporary compressed-air arrangement.

Trashracks.—Wartime priorities on material and manufacture made scheduled delivery of the originally designed trashracks indefinite. To prevent probable construction delay, a substitute trashrack was designed that could be made on the job from available materials. It was half-cylindrical in shape, fabricated from 1¼-inch-square reinforcing steel welded together (fig. 109). Each rack was completely assembled at the machine shop before installation.

Trashracks for sluices 1 to 4 were installed just prior to the second-stage river diversion. Three of the vertical steel rods forming the rack were fitted with steel shoes which were grouted into recesses in the concrete apron at the base of the dam. The sides of the rack were bolted directly to the stop log bulkhead guides. The trashrack for sluice 5 was installed in the same manner shortly before removal of the second-stage cofferdam.

The trashracks for sluices 6, 7, and 8 were fastened to the faces of the concrete piers that formed the second-stage auxiliary cofferdam bulkhead. These piers projected 7 feet upstream from the face of the dam, and their spacing was approximately 2 feet wider than the trashrack unit. The half-cylindrical racks were extended with angles to span the space between the piers, and the extensions were fitted with steel plates which were bolted to the face of the pier with cinch anchors. The racks were supported by welded steel knee braces fastened to the concrete with cinch anchors. The gap at the top between the back of the rack and the sluice opening was filled with screens made of 1¼-inch reinforcing steel.

Spillway gate anchorages

The 12, all welded, steel anchors carrying trunnion pins for the gate bearings were supplied under a separate contract and were installed in the piers as concreting progressed.

Prestressing, or elongation of the anchor bars equivalent to that caused by full water load against the gate, was done by thermal expansion of the steel bars by induced heat produced by electrical hysteresis and eddy current loss, a method noted for its simplicity of operation,

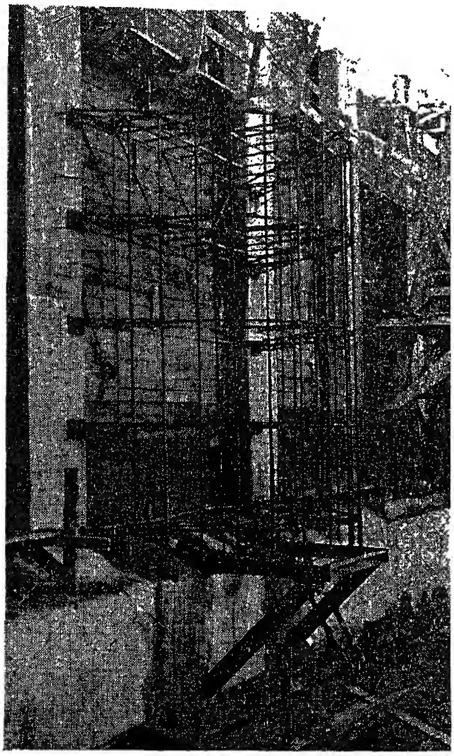


FIGURE 109.—*Sluice trashrack.*

absence of cumbersome apparatus, and flexibility of control. A time interval of 28 days between embedment of the anchor and the prestressing operation was required to allow the concrete to reach full strength. Figure 110 shows the arrangement of the anchorage, and figure 111 shows erection views.

Preparation of the anchorages for prestressing was done before their installation in the piers. The anchor bars were first painted with asphalt and covered with wrappings of burlap and sisal paper. Each bar was wound with 250 turns of No. 8 insulated copper wire, making a total of 1,000 turns for each anchor, and finally covered with sisal paper wrapping. The windings on two bars were connected in series, forming two circuits for each anchor. The use of the asphalt and paper wrappings prevented bond between the steel bars and concrete and permitted free transfer of the anchorage load to the embedded main anchor plate. A minor modification of the Cherokee method, introduced at Douglas Dam, was that of using small-gage wire, doubling the number of turns, and increasing the electrical frequency from 90 to 125 cycles. These changes resulted in a saving of copper and a shortening of the time required to reach the specified elongation of the bars.

In the actual prestressing operation, two micrometer dial gages were placed between the auxiliary bearing plates and small steel rods previously embedded in the downstream face of the pier to measure the bar elongation. At the intermediate piers where the anchors carried a balanced load the specific elongation was 0.072 inch. Expansion of the two pair of bars was maintained evenly by opening and closing each circuit as required. Approximately 4 hours was required to obtain the specified elongation. When this point was reached, as indicated by the dial gages, the space between the auxiliary bearing plates and the downstream face of the concrete pier was filled with a cement-sand grout having proportions of 1 to 1½ with an admixture of 2 percent calcium chloride to accelerate setting. The elongated position of the bars was maintained for a period of 12 hours after grouting by

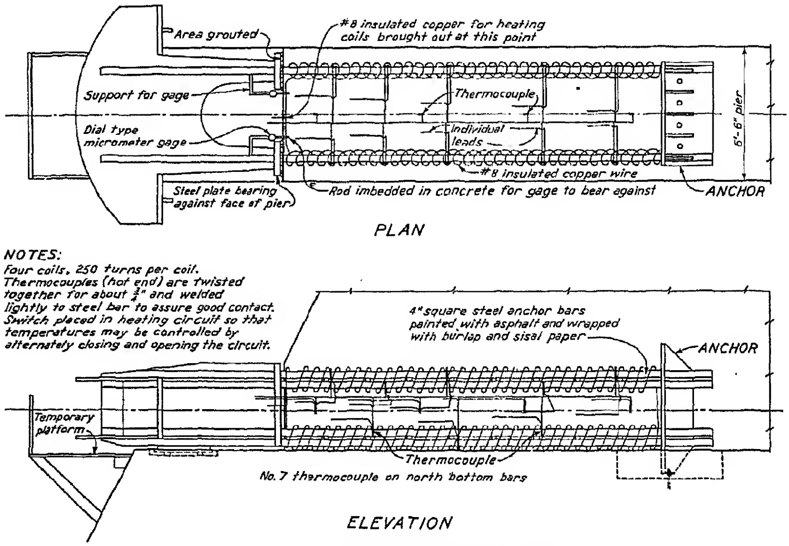
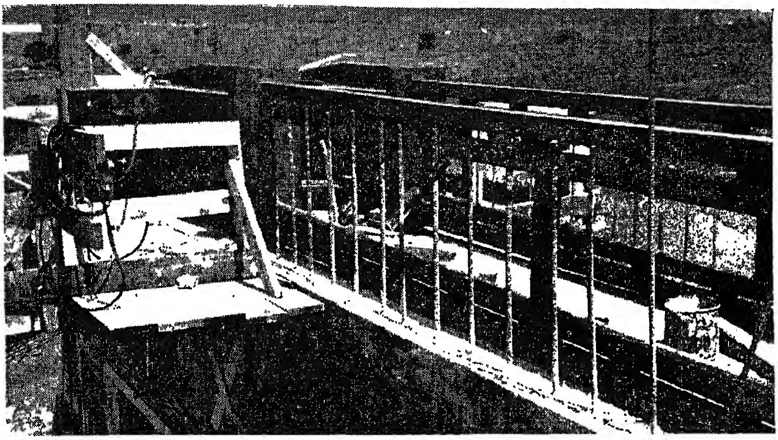


FIGURE 110.—*Electrical prestressing.*

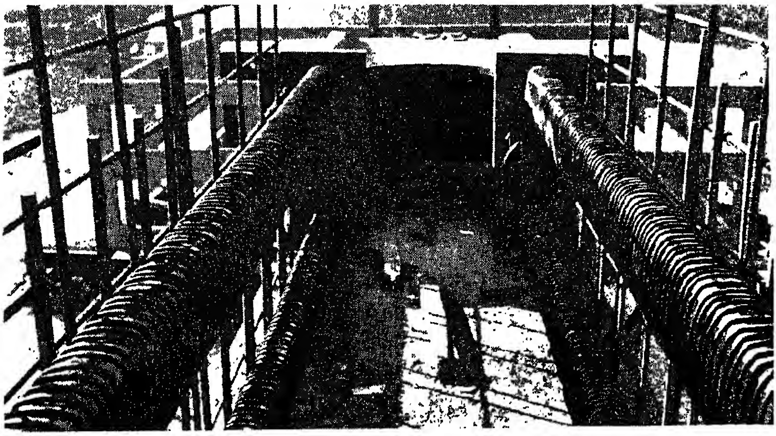
intermittent operation of the electrical circuits. Previous tests on specimens of the grout showed that it would reach a compressive strength of approximately 1,000 pounds per square inch in a 12-hour period.

At the end anchors where the loading was unbalanced the specified elongation for the bars on the gate side of the anchor was 0.106 inch, 0.020 inch for the bars on the opposite side. After the 0.106-inch elongation was obtained by the method given above, the bearing plate in the gate side of the anchor was grouted; and the elongation was maintained for the 12-hour period. The anchorage was then allowed to cool until the elongation of the bars on the opposite side had retracted to 0.020 inch, at which time the bearing plate was grouted in the regular manner.

Two of the gate anchorages, those located in blocks 20 and 24, were not prestressed as described above as a result of apparent partial



a. Before applying heating coils.



b. Heating coils completed.

FIGURE 111.—*Views of spillway gate anchorage erection on Cherokee project illustrate similar methods employed on Douglas.*

short-circuiting of the bar windings. Grouting of the bearing plates in these two anchorages was postponed until the reservoir water level reached normal pool elevation of 1,000, at which time the full hydrostatic load against the gate produced the required bar elongation.

Spillway radial gates

The 11 radial spillway gates were identical to those which had been purchased for Fort Loudoun and Cherokee Dams. To meet the construction schedule at Douglas, 10 of the gates manufactured under the Fort Loudoun contract were transferred to Douglas Dam. The Douglas contract was used to fill the Fort Loudoun requirements at a later

date. The one remaining gate, the last to be installed, was received directly from the manufacturer. Figure 20 shows the spillway gate arrangement.

Gate erection.—The lower section of each radial gate, including the main gate frame and skin plate, was first assembled in the switchyard area adjacent to the construction bridge. It was then accurately squared, leveled, and riveted; and the skin plate joints were welded.

The gate radial arms were first placed on the anchor trunnions and alined as the concreting of each pier was completed. At the same time, the sill beams and wall plates were installed in the recesses formed in the spillway crest and pier faces and adjusted to position by means of anchor bolts and jack screws. The normal practice of grouting in the sill beams and wall plates after the gate was in final position was followed only with gates 1 to 4 because of the time limit imposed by the rapidly filling reservoir. For the remaining seven gates the grouting was done before the gate was installed.

The assembled gates were handled during installation by two gantry cranes operating together. They were lowered into the bays (fig. 112), were rested on temporary timber cribs about 3 feet high set on

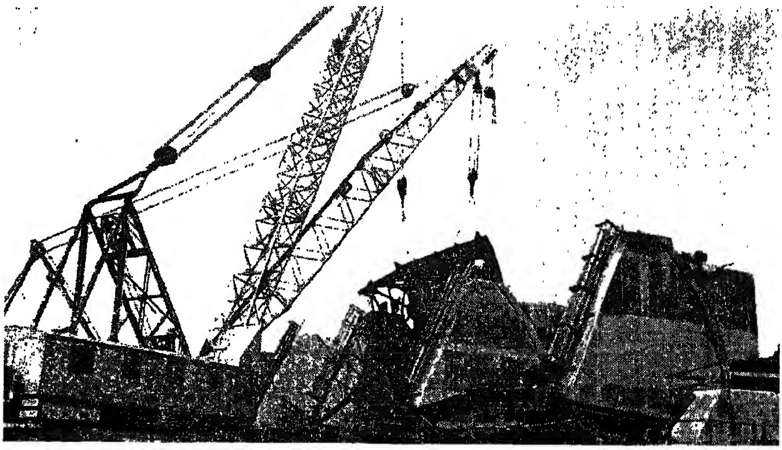


FIGURE 112.—*Spillway crest gate erection.*

the spillway crest, and were held in position by the cranes until the radial arms were bolted on. After final adjustment the riveting was completed, the rubber seals at the bottom and sides of the gate were installed, and the gate was then lowered to the closed position. Erection of the upper section of the gate was then completed. This sequence permitted water storage above the crest before the gates were finished.

In bay 5, where the last spillway gate was installed, late delivery of the gate prevented its installation before the reservoir water level reached the spillway crest. To avoid interruption of water storage, this bay was closed with a temporary concrete bulkhead 15 feet high. The bulkhead was designed by the field drafting room and consisted of four reinforced-concrete gates placed in a steel frame spanning the

upstream side of the bay. Installation of the gate behind the bulkhead was completed when the reservoir was 7½ feet above the spillway crest.

Spillway operating bridge

Approximately 346,180 pounds of steel for the operating bridge was fabricated and delivered under contract and included stringers, bearing plates, and supports for the dogging devices used to hold the spillway gates in the raised position. In this tonnage was 123,180 pounds of 4¼-inch I-beam interlock steel flooring, which was delivered to the job in panels. Figure 113 shows the steel flooring and hoist rail before concreting.

Construction of the bridge followed the installation of the radial crest gates. The gate dogging devices were temporarily bolted to each pier to permit the erection of the superstructure. The bridge deck was supported on three lines of 33-inch 125-pound wide-flange steel beams with lateral bracing diaphragms. Each beam spanned two spillway bays with the fixed anchorage on the center pier and the expansion anchorage at the end piers. The beams were placed in position with a construction gantry crane, set to line and grade, and grouted in place.

The prefabricated panels of steel I-beam interlock bridge flooring were next welded to the deck beams. The 3-inch-square steel rails for the traveling gate hoist were welded directly to the deck panels. The 7-foot spacing of the rails located them directly over the two downstream deck beams. As installation of the deck panels and hoist rails progressed the panels were filled with concrete.

Traveling gate hoists

The two traveling gate hoist cars were delivered fully assembled. They were placed in position on the operating bridge with two construction gantry cranes.

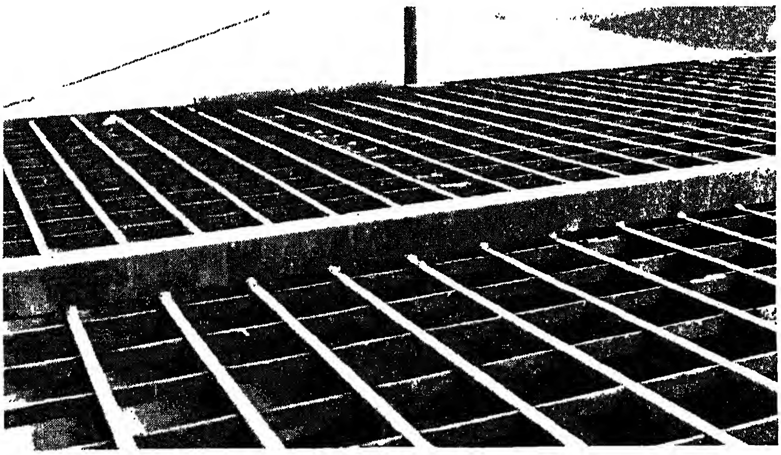


FIGURE 113.—*Steel flooring and hoist rail before concreting.*

INTAKE

The intake section is included in blocks 12 to 16 of the dam. Block 12 is the transition block between the north nonoverflow section and the intake section and contains the elevator shaft extending from the powerhouse control room floor to the top of the dam and the spiral staircase extending below the control room to the drainage gallery. Blocks 13 to 16 contain the four penstocks leading to the generating units in the powerhouse.

Intake trashracks

Construction of the four intake trashracks followed concreting in the dam. The intake gate guide piers, which also formed the anchor columns of the trashrack, were placed with the block pours; and as block concreting progressed recesses were formed in the piers for the trashrack strut beams. Three cast-in-place columns formed the corners of the semioctagonal structure. The guide channel assemblies were first set up on the foundation, and the column forms were built around them and filled with concrete to the bottom of the first strut beam. The precast strut beams were then set between the columns, and the next column lift was formed and poured. The beams joined the intake gate guide piers at recesses in the piers, which were filled with grout. The steel trash grilles were delivered completely assembled and were lowered into position by a 40-ton gantry crane on the construction bridge. A Chicago boom erected on a steel beam placed across the top of the gate guide piers handled all the material for the structure.

Intake gates

Intake gates were installed at the intake openings of penstocks 1, 2, and 3; penstock 4 was closed with a hemispherical steel bulkhead. Prior to the installation of the permanent steel gates, temporary timber bulkheads had been placed across the openings to prevent flooding of the powerhouse.

Gate guides.—The steel gate guides were delivered in sections 10 to 15 feet long. They were installed in advance of concreting and were embedded as concrete placement progressed. Special care was taken to set and hold them to line and grade.

Before the gates were installed the guides were sandblasted and painted with one coat of cold bitumastic primer, followed by one hot application of bitumastic enamel.

Fixed seals around penstock openings.—The stainless steel seal plates welded to heavy structural steel slabs were delivered in sections 8 to 15 feet long. The plates were installed in each opening in their proper relation to the gate guides, which insured a maximum area of contact between the plates and gate seals along the sides. The sections were bolted to the gate guide with stainless steel stud bolts, which, in conjunction with jack bolts, were used to adjust the plates to position. At the top and bottom of the opening the plate sections were fastened and adjusted to horizontal structural steel face plates embedded in the concrete during construction. When final adjustment of the seal plates was completed, melted white filler metal was poured into the space between the structural steel slabs and the gate guide.

Gate assembly and installation.—Gates for penstocks 1 and 3 were assembled on the decks of their respective trashracks with a gantry

crane (fig. 114). The lower section of the gate was set in position on 8- by 8-inch timber blocks with the bottom at the elevation that would permit the guide castings on the gate to enter the slots in the gate guides. It was held in place with turnbuckle tie rods and timber thrust struts.

The upper section of the gate was then set on top of the lower section; and after careful adjustment the center section of the skin plate was welded in place, thus completing assembly of the gate leaf.

The end post assemblies were then bolted to the gate leaf. Before proceeding with further assembly, the gates were painted with one

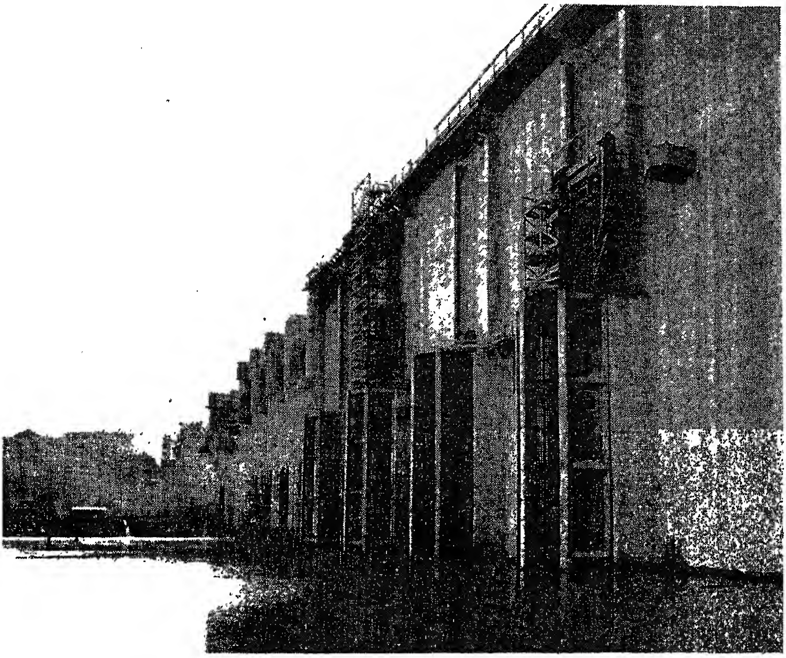


FIGURE 114.—*Intake gate assembly on deck of trashrack structure.*

cold prime coat of bitumastic paint, followed by a hot application of bitumastic paint and a hot application of bitumastic enamel. Prior to the installation of the roller train assemblies, stiffener angles were bolted along them to prevent distortion while lifting them to a vertical position. They were then bolted in position in the end posts.

The rolled naval brass gate seals were held in position by steel retainers. The surfaces to which the seals and retainers were attached were thoroughly cleaned and the outer retainer bolted in position, the seal plates with their spring inserts were installed, and the inner retainer bolted in place to complete the assembly.

Because of the late delivery of No. 2 gate, reservoir water level was too high when assembly began to erect the gate on the trashrack; and it was assembled on top of a 20-foot-high steel tower made of four 8-inch

wide-flange columns, cross braced with 3-inch pipe, which stood on top of the trashrack deck. After the gate had been set in the guides, the platform was merely slipped off the dowels and removed. Special slots were cut in the concrete guide piers and outer flange of the gate guides to permit the gate to be slipped into the guides.

The permanent hoists were used to set the gates into the guides, assisted by auxiliary tackle and the 40-ton gantry cranes.

Intake gate hoisting equipment.—Complete gate hoisting equipment was installed for each of the three gates, and base plates were set for the future completion of the fourth gate. Each set included two hoists and speed reducers with chains operated by a single 50-horsepower electric motor.

Penstocks

The downstream sections of the 19-foot-diameter penstocks were lined with steel plates furnished, fabricated, and installed under contract.

Field fabrication.—Field fabrication and assembly of the penstock liners were done at the south storage yard approximately 1 mile downstream from the dam. Each liner was assembled in three principal sections: the downstream straight section of four rings, the curved elbow midsection of four rings, and the upper end straight section of two rings. The rings were brought to round with an 18-bolt spider and riveted together. The completed liner section was hauled to the dam on a tractor-drawn trailer.

Liner installation.—The steel liners were supported by 11 structural steel saddles which were set to line and grade and anchored to previously embedded anchor bolts and held in a rigid position by welded cross bracing. The three sections were lowered onto the saddles (fig. 115) with a 40-ton gantry crane operating from the construction bridge. The downstream straight section was placed first, followed successively by the elbow section and the upper straight section. The three sections were then bolted together, and following final adjustments of line and grade they were welded to the saddles and riveted. Steel tie-down bars were welded to the liner and to embedded steel dowels to prevent uplift during concreting. The stiffening spiders remained in place until the steel liners had been covered with a minimum of 10 feet of concrete.

Prior to placing concrete around the liner, a ½-inch-thick cushion of cork-tar mastic was applied on the outside to the upper 270 degrees of the circumference for a distance of 10 feet upstream from the face of the penstock scroll case connection recess. This cushion permitted slight movement due to temperature changes and vibration without injuring the concrete. The interior of the penstock liners was thoroughly cleaned by sandblasting and painted with one coat of cold bitumastic prime and one hot application of bitumastic enamel.

Hemispherical steel bulkheads.—Pending the installation of power unit 4, a hemispherical steel plate bulkhead was installed at the upstream end of the penstock liner to replace the regular intake gate; and following cancellation by the War Production Board of the installation of power unit 2 the same type of bulkhead was also placed in the penstock of unit 2. Both bulkheads were furnished by the contractor, who installed the one in penstock 4 as part of his contract. Installation of the penstock 2 bulkhead was done by the TVA.

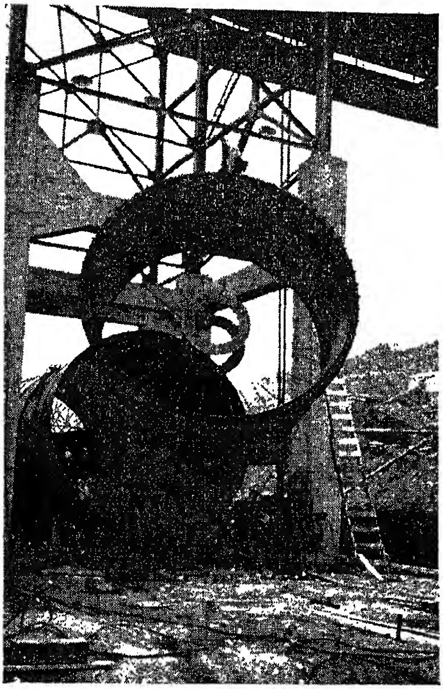


FIGURE 115.—*Assembly of unit 1 penstock liner.*

The bulkhead in penstock 4 was installed before the liner was embedded in concrete, and the assembly was entirely riveted. Installation of the bulkhead in penstock 2, however, did not start until after the penstock had been embedded in concrete; and the major part of the assembly was welded. A 6½- by ½-inch steel collar was welded to the inside of the penstock liner to which the bulkhead was welded. The plate seams were welded at and away from the bulkhead collar connection until sufficient clearance was obtained to operate riveting equipment, and the remainder of the plate seams were riveted.

POWERHOUSE

Only units 1 and 3 were installed initially; the installation of unit 2 having been canceled by the War Production Board. Construction of the powerhouse, however, was completed to enclose units 1, 2, and 3. For future unit 4 the draft tube was completed, and the powerhouse walls were carried to the elevation of the draft tube gallery, leaving the upper part of this section of the powerhouse open.

Interior walls

Only those rooms and offices which were essential to the operation of the plant were completed initially. The floors of the powerhouse are of reinforced concrete and are supported by the structural steel framework of the building. Concrete brick and structural non-load-

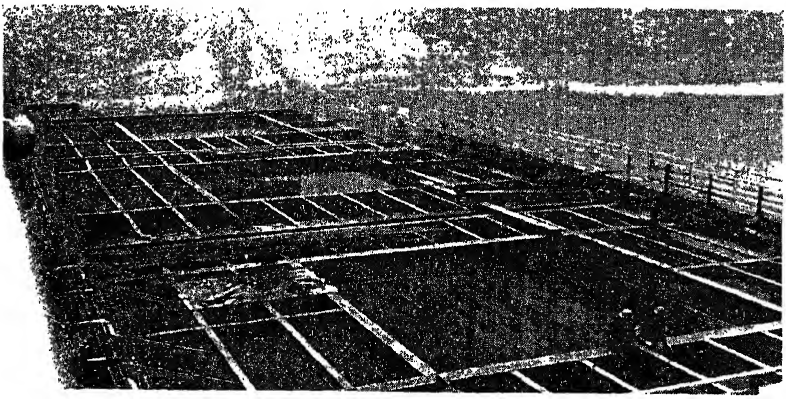
bearing terra cotta tile covered with plaster were used for the interior walls.

Powerhouse and control building roof

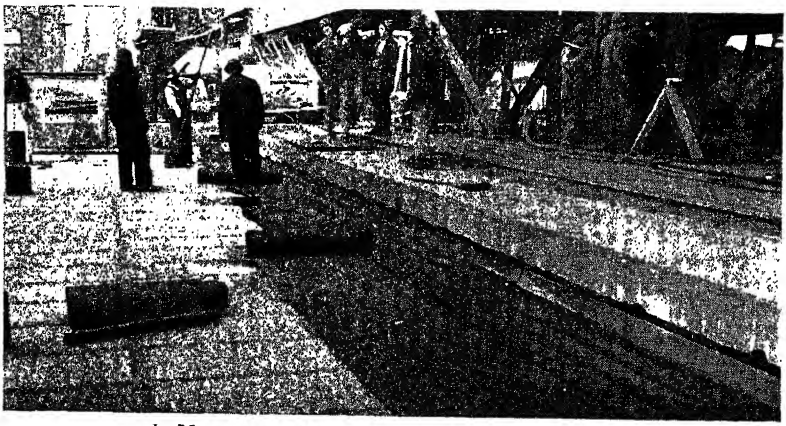
The powerhouse and control building roof is of precast concrete slab construction. Precast concrete panel roof slabs were placed directly on the steel roof beams; and a bonded, membrane, felt roof was mopped over them. Precast reinforced-concrete deck slabs were then placed over the membrane roof. Figure 116 shows the roof structure over the generator room.

Draft tubes, gates, and guides

The draft tubes are of the single vertical elbow type with double discharge and, with the exception of a short steel liner just under the turbine, are formed of concrete. One pair of structural steel gates



a. Steel framing.

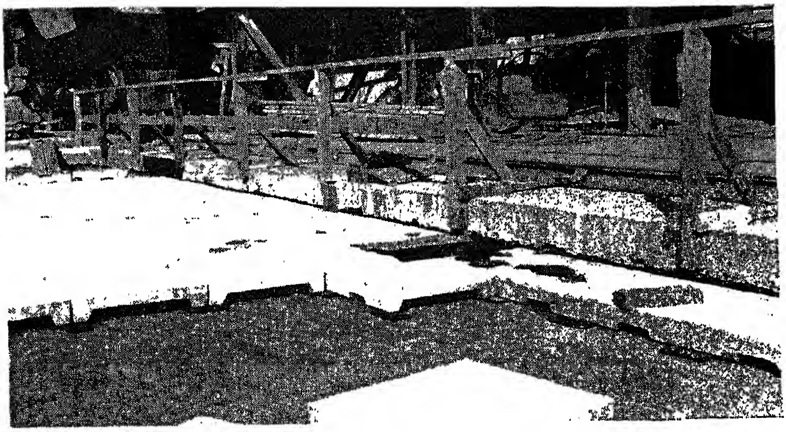


b. Mopping roofing paper on precast concrete slabs.

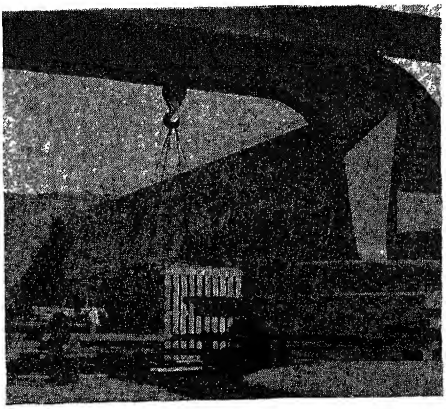
FIGURE 116.—*Roof*

and two pair of bulkheads (structural steel frames with timber face) were installed for closing the six draft tube discharge openings of units 1, 2, and 3. None were provided for unit 4. The gates and bulkheads are interchangeable and can be shifted as required. With the exception of the rubber seals and timber lagging on the bulkheads, they were fully assembled when delivered. All exposed steel surfaces of gates and bulkheads were sandblasted and painted with one prime coat of bitumastic paint, followed by one hot application of bitumastic enamel.

The gate guides, delivered in sections 12 to 16 feet in length, were embedded in the concrete as it was poured. The gate seal at the bottom on an H-beam embedded in the floor of the draft tube and the horizontal seal beam at the draft tube roof were attached to the



c. Precast slabs laid over membrane.



d. Completed roof and removable hatch covers.

over generator room.

guides. Dogging hooks to hold the gates in the open position were installed for units 1, 2, and 3.

The gates are operated with an auxiliary jib crane on the downstream end of the powerhouse crane. After the construction of Douglas Dam was completed one set of bulkheads was transferred to Fontana Dam.

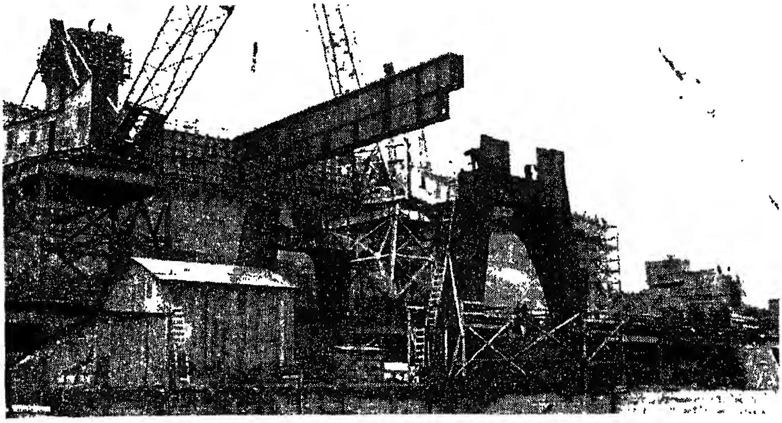


FIGURE 117.—*Erection of powerhouse gantry crane.*

Powerhouse crane

The 225-ton powerhouse crane was erected in place on the crane track with construction gantry cranes (fig. 117). The wheel trucks were first placed on the rails and the crane legs were then set on them. The legs were guyed off, and the two main girders were placed; each girder required two cranes to lift it. When riveting was completed the trolleys and other mechanical and electrical equipment were installed. Load and operation tests were made with loads 25 percent larger than the rated capacity.

Turbine installation

Because of wartime restrictions, the procurement of the turbines for units 2 and 3 was canceled by the War Production Board. One complete unit that had been received but not installed at Cherokee Dam was transferred to Douglas Dam and installed as unit 3. Unit 1 was received directly from the manufacturer under the Douglas Dam contract. The two turbines were of the vertical Francis type, rated at 41,500 horsepower at 100-foot head and at normal speed of 94.7 revolutions per minute. The runners were 177 inches in diameter. The turbines were manufactured by the S. Morgan Smith Co. and were installed by the TVA's forces under the supervision of the manufacturer's representative.

During erection, the 40-ton gantry cranes, either singly or in pairs, were used almost exclusively in handling and placing the various parts. Since the construction method used for both units was essentially the same, the following description of erection procedure applies to either unit 1 or 3 except where noted.

Embedded parts.—Embedded parts of the turbine were installed in the following order: draft tube liner, curb ring, speed ring, scroll case, and pit liner. The steel plate draft tube liner was received in two half-sections, which were welded together, leaving the top 2 feet of the vertical joints open for easier fitting to the curb ring. It was held in position with turnbuckle tie rods, and pipe jacking spiders were placed at the top and bottom to keep it in round while concrete was placed in the recess around it. Concrete was placed in four lifts to approximately 2 feet below the top, the inside surface being sprayed with water during the pouring and for several days afterward to dissipate the heat and reduce expansion and subsequent separation of the liner from the concrete.

The curb ring was also received in two half-sections, which were bolted together and set in place on the draft tube liner (fig. 118). The

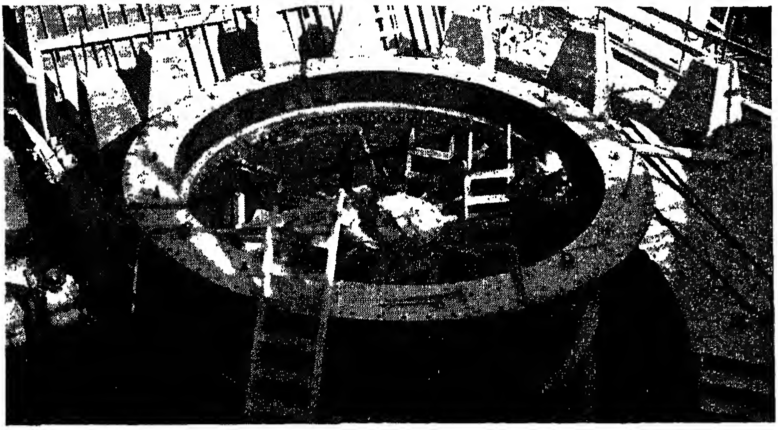


FIGURE 118.—*Installing curb ring on draft tube liner.*

curb ring was supported and leveled with eight 30-ton jack screws and seven steel H-columns with steel plates and shims.

With the curb ring in correct position, the two halves of the speed ring were set on it, bolted together, and then bolted to the curb ring (fig. 119). Before tightening the bolts, it was brought to round and concentricity with eight-leg spiders at the top and bottom flanges of the speed ring. Checks for concentricity and level of the speed ring were made daily during erection of the scroll case. While concrete was being placed around the scroll case, checks were made before and after the first placement and after each of the remaining placements.

Assembly of the steel plate scroll case began at the wye and progressed clockwise in the direction of increasing diameters. Complete initial assembly of the plates was made by 50 percent bolting before riveting started. This afforded sufficient flexibility to permit final adjustments of the speed ring, scroll case, and penstock connection within the small tolerances permitted. Approximately 8,000 rivets of various sizes and lengths were driven in each scroll case, after which the plate joints were caulked and the crotch plates welded in place (see fig. 120).

During assembly the case was supported around its outer perimeter by 24 screw jacks set on small concrete piers, and 10 additional jacks were placed beneath it at the flow line for additional support. Heavy timber framework was installed inside to maintain its shape during concreting. Final connection of the scroll case to the penstock was deferred until after concreting was completed and the temperature

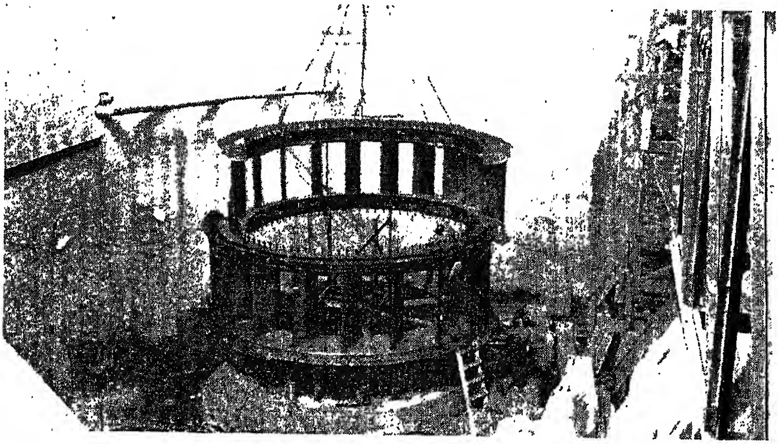


FIGURE 119.—*Speed ring erection.*

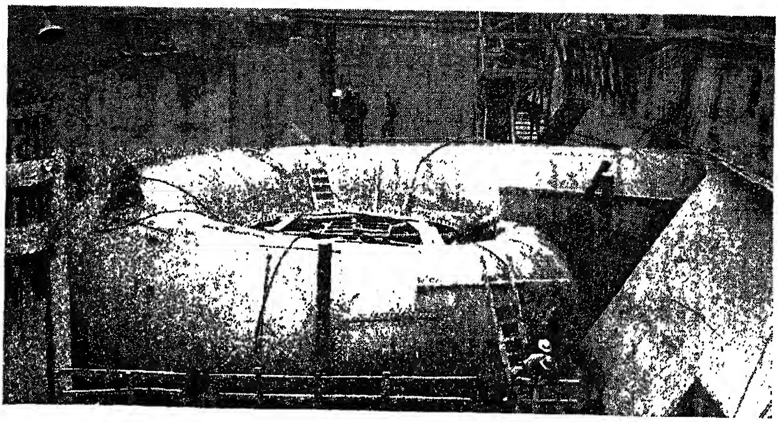


FIGURE 120.—*Scroll case erection.*

of the concrete around the scroll case had fallen approximately 50 degrees. The interior surfaces of the draft tube liner and scroll case were wire brushed and painted with three coats of underwater paint.

The three sections of the steel pit liner were bolted together on the speed ring, and after a final position check of the liner and servomotor faces it was bolted to the speed ring and an adjustable spider placed at the top to maintain its shape during concreting.

Concreting.—Concrete around the scroll case was placed in 10 lifts averaging about 2 feet in thickness, placed at the rate of one lift per day. Around the pit liner the lifts varied from 3 to 5 feet in thickness to suit design features. Cooling water coils were installed in the scroll case concrete, water was circulated through them continuously during concreting and for 7 days after completion, and cooling water was sprayed continuously over the scroll case interior.

The space under each scroll case adjacent to the bottom of the speed ring became inaccessible when concreting reached the bottom of the scroll case. This void was filled with grout to within about 3 inches below the curb ring plate through six 10-inch-diameter pipes. The grouting was completed through 2-inch pipes placed in 27 holes provided in the lower speed ring flange for that purpose. To insure complete filling, the grout was rodded through the pipes until it rose through all the forty ¾-inch vent holes previously drilled through the top of the curb ring. After grouting was completed all holes were plugged and ground flush.

Internal and operating parts.—After concreting had been completed to the generator subfloor the pit was prepared for installing the operating parts of the turbine.

The two half-sections of the bottom plate were bolted together and placed in position inside the speed ring on its lower flange and temporarily bolted to the curb ring. Ten of the twenty cast steel wicket gates were set in alternate positions in the bottom plate; and the upper plate was then lowered over the gates until it rested on the upper flange of the speed ring, where it was temporarily bolted and doweled with 4 of the 10 dowels.

The top plate was then removed, the bottom plate doweled to the curb ring, and the remaining 10 gates installed. The turbine runner

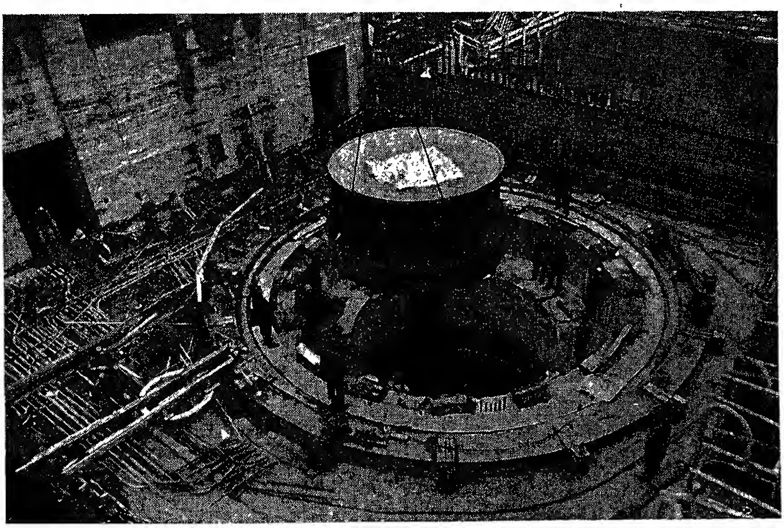


FIGURE 121.—*Installing turbine runner.*

was then set in place (fig. 121), and the top plate was replaced and bolted and doweled to the speed ring.

The 15-bucket steel turbine runner, cast in a single piece, was lowered into position onto leveling shims previously set on the curb ring lip and then centered in the bottom plate and held in position with shim stock at the four center line points (fig. 122).

The shaft was lowered into place and bolted to the runner, with the nuts being sledged tight until all were seated at the same tension, then permanently locked by tack welding. The top of the shaft coupling was level in all directions.

The servomotors, operating ring, wicket gate arm assemblies, turbine guide bearing housing, and links were then installed and adjusted (fig. 123).

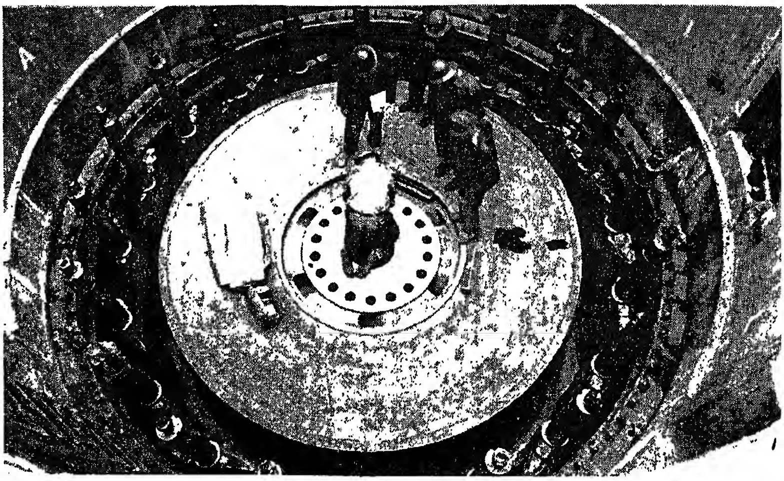


FIGURE 122.—*Turbine runner in place.*

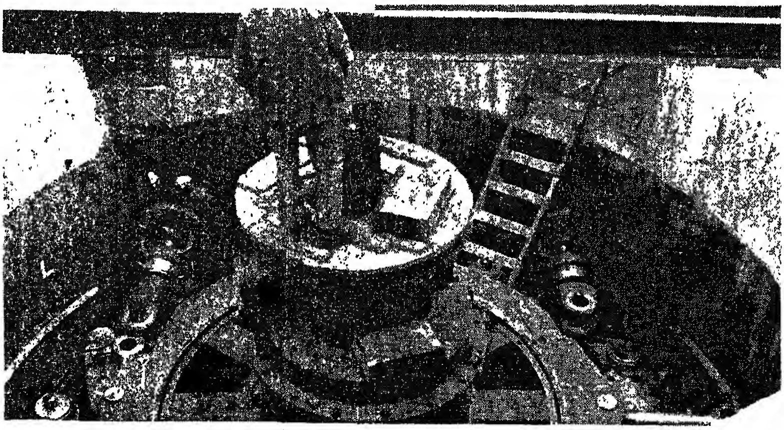


FIGURE 123.—*Guide bearing housing, shaft, and servomotors.*

Governors.—The turbine governors were of the cabinet actuator type, manufactured by the Woodward Governor Co. They were installed in the control room by the TVA's forces under the supervision of the manufacturer's representative. For units 1 and 2 a twin governor in a single cabinet was supported on a temporary structural steel bracket overhanging the pit provided for unit 2, [illegible] governor for unit 3 was installed. They were of the relay valve "actuator" type with motor-driven governor head, complete with auxiliary control mechanism, cable-type restoring mechanism, oil pressure system, instruments, and gages. The latter included a temperature recorder for all important points around the unit. Recording thermometers for cooling water, headwater gage, indicating and totaling flowmeter, turbine guide bearing oil pressure and temperature gages, generator guide and thrust bearing temperature gages, thrust bearing oil level indicator, and CO_2 fire-protection system control switch.

Generator installation

The two generators for the Douglas Dam initial power installation were designed, manufactured, and installed by the General Electric Co. They are the vertical hydro, 3-phase alternating-current type, rated at 33,333 kilovolt-amperes at 94.7 revolutions per minute, and generating at 13,800 volts, and are equipped with Kingsbury thrust bearings.

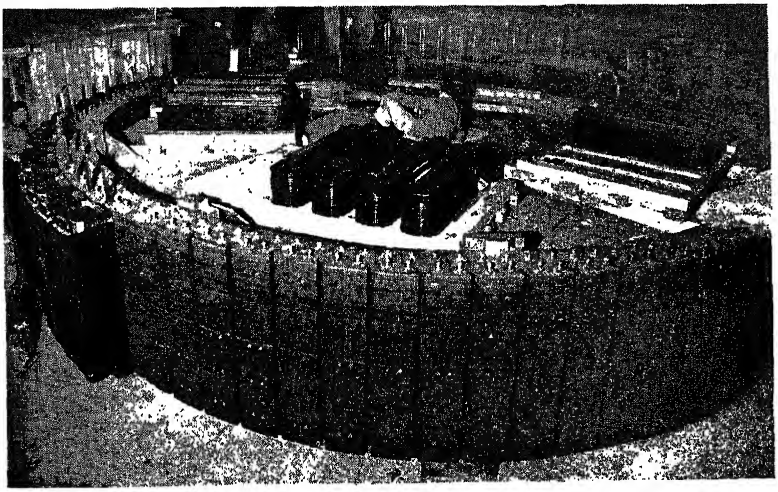


FIGURE 124.—*Rotor assembly.*

Rotor assembly.—In assembling the rotor (fig. 124), the lower hub plate was bolted to the assembly pedestal; and the ten 36-inch I-beam arms were bolted to the hub plate. The outer ends were blocked up and leveled, and the top hub plate was then bolted to the arms. Both plates were bolted with identified turned bolts and locked by tack welding. The brake plates were then assembled around the lower

perimeter, the lamination or rim bolts installed, and the assembly of the laminations was begun.

The hot-rolled sheet-steel punched laminations were first weighed, then dropped over the rim bolts and keyed to the rotor arms with tapered rim keys. Each layer contained plates of equal weight which distributed the weight equally around the rim. The laminations were compressed at intervals and after complete assembly (4 feet 3 inches high) were securely tightened by sledging the rim bolt nuts and locking them by tack welding. The tapered rim keys were then driven to refusal with sledge and pneumatic hammers, and key blocks were set at the top of each rotor arm.

The pole slots in the rotor rim were then filed out with a job-devised tool consisting of two square files fitted into an expander frame containing a spring for each one and a hook at the top for attachment to the overhead crane hook. The filing tool was started into the slots at the bottom and pulled upward through them by the crane until the inside surfaces of the pole slots were smooth.

With rope sling, using the service bay trolley crane, the pole pieces (pole and coil) were lowered into the rim slots, held in place with a pair of tapered steel keys set on each side of the dovetail, and driven to refusal with sledge and pneumatic hammers.

The field pole coil leads were then thoroughly cleaned with emery paper and an acid solution, and silver soldered. Feeder leads from the exciter were installed along the top or rotor arm 10 on insulating blocks, taped and painted with insulating material and black varnish. The field circuit resistance was then measured, tested dielectrically with 6,500 volts for 1 minute, and the polarity of each pole checked.

After checking the shaft opening in the hub plates for concentricity to ensure a perfect fit of the rotor on the shaft, it was ready for installation.

Thrust bearing bracket and bearings.—The generator thrust bearing bracket, thrust bearing, and generator shaft were assembled in one unit on the service bay deck. The thrust bearing bracket which carries the welded steel plate housing is made of welded steel girders. It is supported in the pit by six billet steel sole plates, each anchored by four 2-inch-diameter anchor bolts in recesses formed in the concrete. After being leveled at the same elevation the plates were set in grout.

With the bracket blocked up about 4½ feet above the floor, the shaft was lowered through the bearing housing and blocked up a height sufficient to allow the assembly of the thrust bearing and runner plate in the bearing housing and around the shaft. The oil pan was then assembled to the bearing housing, sealed with a velumoid gasket, and bolted. The housing cover plates were then temporarily placed, sealed, and bolted, and the bearing oil chamber checked for oil tightness by filling it with kerosene for 24 hours.

A timber assembly bed was built on each side of the housing, on which the bearing assembly was made in halves; then each half was slipped into place in the housing. The cage was first bolted down to the housing, and then the runner plate was bolted together and rotated to its proper position. The shaft was lowered down on the runner plate, and the runner plate was bolted and doweled to the thrust block. The generator guide bearing, located directly above the thrust bearing, was then installed.

Shaft coupling.—The bearing bracket assembly was lowered into the generator pit with the powerhouse crane and adjusted to correct elevation above the turbine shaft coupling. Temporary 4-inch coupling bolts were placed in alternate holes in the shaft flanges, and the nuts were tightened until the two shaft flanges were in contact. Nine permanent coupling bolts were jacked into the open flange holes between the temporary lifting bolts, and the temporary lifting bolts were then removed and replaced with the remaining nine permanent coupling bolts. All nuts were then tightened until the bolts had an equal stretch of approximately 0.006 inch. The shaft was plumbed by adjustment of the thrust-bearing shoes, using an electric micrometer from four equally spaced plumb wires. After the shaft had been alined to final position by the generator erector the two halves of the turbine guide bearing were bolted together around the shaft, alined with the assembly match marks, lowered into place in the bearing housing, and bolted down.

Stator.—After calculating the final elevation of the horizontal center line of the rotor, the stator sole plates were set so that the rotor would be centered vertically in the stator. Allowances were made for deflection of the bearing bracket due to water load on the water wheel and the weight of the rotor.

The four stator sections were then set on the sole plates (fig. 125) with the powerhouse crane and bolted together; then the assembled stator was accurately centered with reference to the generator shaft.

With centering, concentricity, and leveling adjustments completed, the sole plates were grouted permanently in place. The quadrants of the stator were received from the factory already wound, and it was

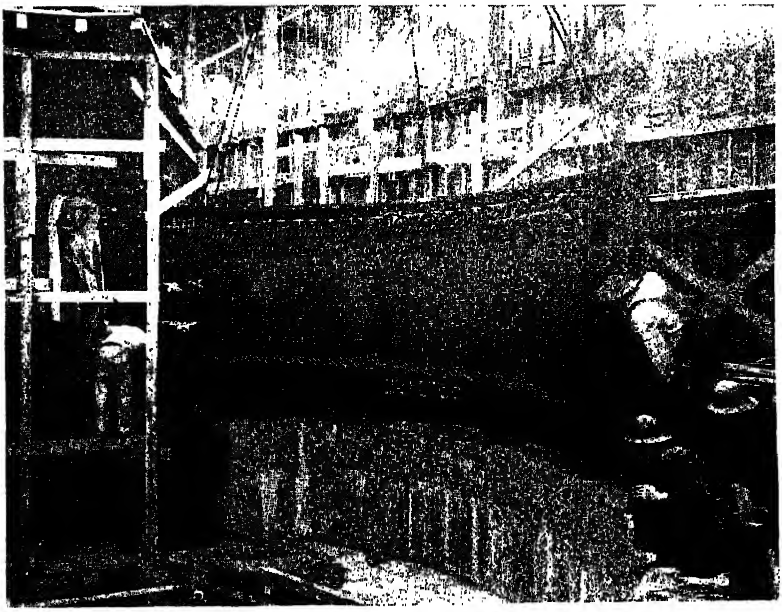


FIGURE 125.—*Placing stator quadrant.*

only necessary to install the armature winding coils and circuit connections across the joints. The coils in the slots near the joints were heated and bent back out of the way so that the new coils could be installed in the bottom of the core slots, and then they were bent back into the top of the slots. The new coils were also heated for installation. The heating was done with direct current from 600 to 1000 amperes at 12 volts, furnished by portable motor generator equipment. Heating the coils to around 80° centigrade permitted safe bending without danger of damage to the mica-base insulation. Each new coil installation and each original coil replacement was dielectrically tested with 33,000 volts for 1 minute. With all coils installed, the circuit connections were completed, the coil interconnections made, and all connections wrapped with rubber, mica, and fabric insulation, and painted with one coat of glyptal and two coats of black varnish. The completed sections of field winding were then dielectrically tested as before.

Rotor installation.—Following completion of the stator, the rotor was installed, using the 225-ton powerhouse crane to place it on the shaft (fig. 126). The top and bottom hub plates were bolted to the shaft and slugged tight. The combined exciter and pilot exciter rotors were then installed on top of the main shaft.

The thrust bearing was adjusted to equalize the load on the shoes; and the shaft was checked for alinement, plumb, and run-out. The thrust-bearing bracket was bolted and doweled to the sole plates, the turbine guide bearing was assembled and installed, and the generator guide bearing shoes were placed and adjusted. The various temperature indicators and the generator guide bearing oil vapor guard were

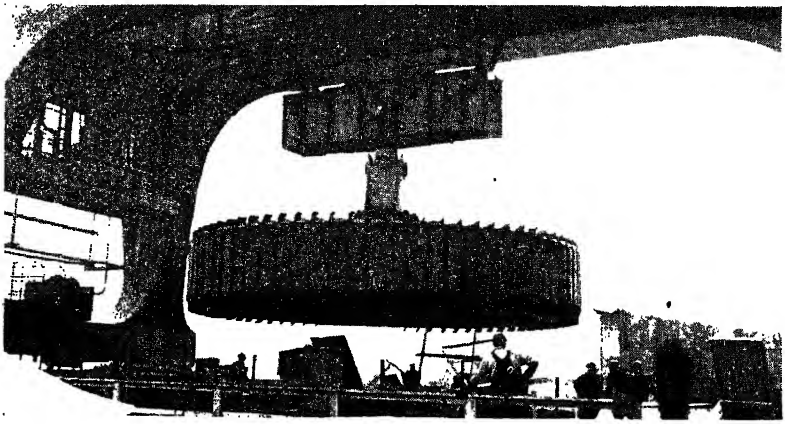


FIGURE 126.—*Unit 3 rotor.*

also installed; and erection was completed with the erection of the combined main and pilot exciter frames, coolers, and generator housing.

Test operation of units

A mechanical test run was conducted on each unit to determine the fitness of the bearings, cooling water system, and other mechanical features. After satisfactory mechanical operation, the short-circuit dry-out or heat runs were made, followed by the high-potential tests.

Unit 3 tested out satisfactorily, but considerable electrical trouble was experienced during the tests on unit 1.

When an effort was made to place unit 1 on the first heat run, the pilot exciter failed to deliver voltage. After exhaustive tests to determine the trouble, it was discovered that several armature coils were short circuited in the loops at the commutator end. The entire pilot exciter was, therefore, removed and returned to the contractor for repair.

The first high-potential tests were begun immediately following this heat run. This consisted of the application of a potential of 28,600 volts for 1 minute on the separate phase windings of the main armature. Phases A and B tested satisfactorily, but phase C failed after 15 seconds. A second application reached only 28,350 volts before failure; and to locate the point of trouble, a third application was made, which reached only 26,400 volts before failure, setting fire to the winding insulation. Fourteen cylinders of CO_2 extinguished the fire. Examination showed that the top loops of two coils in the south quadrant had grounded to the reinforcing ring, and that the fabric taping and varnish insulation of the top-coil loops and circuit connectors and the wooden-block supports had burned over a length of about 10 feet. A large quantity of soot was deposited throughout the entire winding of both stator and rotor.

The defective coils were removed, repaired, and replaced; and a second heat run was made, followed immediately with the second high-potential test.

This time 75 percent of initial test voltage, or 21,000 volts, was applied for 1 minute to each phase of the stator winding; and 3,750 volts was applied for 1 minute to the main exciter commutating pole and series field windings and terminal circuit; all results were satisfactory. The contractor had previously tested phase C at 30,000 volts for 1 minute immediately after completing the winding repairs but before reassembly.

Following the high-potential tests, the CO_2 test was run; and unit 1 was placed on the line and loaded to 9,000 kilowatts. After 10 minutes of operation, one of the coils in phase C failed in the core slot. The intial bank of CO_2 was discharged to prevent fire. Disassembling again and extracting the defective coil, an examination revealed two or more short-circuited turns which had caused the copper winding to melt under load current and to blow out through the insulation, grounding the winding to the core. Molten copper distributed around the core in the ventilation ducts was cleaned out, and a small fused spot in the laminated core slot was ground and separated. A new coil was installed, the winding repair completed, tested at 28,600 volts for 1 minute; and the unit was ready for the third heat run.

At this time the third high-potential test of the stator windings was applied, duplicating the second test; and in addition, 3,750 volts was applied for 1 minute to the rotor field windings. The result was satisfactory.

After satisfactory completion of the high-potential tests, the units were placed on the line until they were subjected to the load-rejection tests which were run on the generator, turbine, and governor as a unit. Loads were rejected from 16.5 to 100 percent of full load. These tests were followed with an index test on the unit to check the efficiency, rating, and guaranties.

A 130-percent overspeed test of 128 revolutions per minute was run first, after which the governor was checked and adjusted for frequency or normal speed control.

Miscellaneous power plant equipment

Other equipment of various kinds includes the following: compressed air and vacuum cleaning, telephones, CO_2 fire extinguishing, treated water, heating, ventilating, and air conditioning, oil purification, carrier current, raw water, and plumbing and drainage.

Accessory electrical equipment

In the main control room of the powerhouse there are located the following switchboards: the main control board, consisting of the five-panel instrument, relay, and benchboards; the six-panel recording instrument board; and the five-panel direct-current distribution board. The instrument board, relay board, and benchboard were received unwired and were wired by TVA forces. The recording instrument board and the direct-current board were received completely wired. The 440-volt auxiliary power boards and the heating, lighting, and air-conditioning boards were received completely wired.

Other equipment included the neutral reactors and oil circuit breakers, the annunciator system with its relay rack, the storage batteries and motor generators, and the station service transformers.

SWITCHYARD

The initial switchyard installation included three single-phase, 161-kilovolt transformers, three bays of switchyard structure, and equipment for the two generating units. Concrete footings for the equipment serving a third generating unit were completed, but installation of the remaining switchyard facilities was deferred pending the installation of unit 2 at a future time.

Prior to placing concrete in the various footings, steel H-section piling was driven to rock to support each of the main steel towers. All

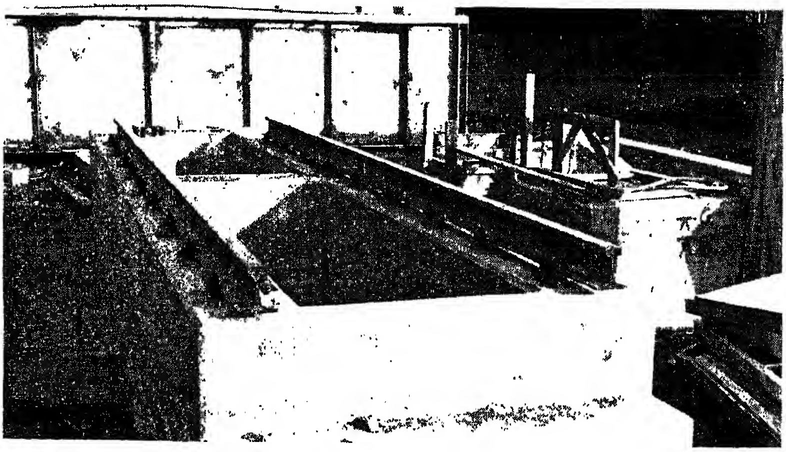


Figure 127.—*Main transformer foundation.*

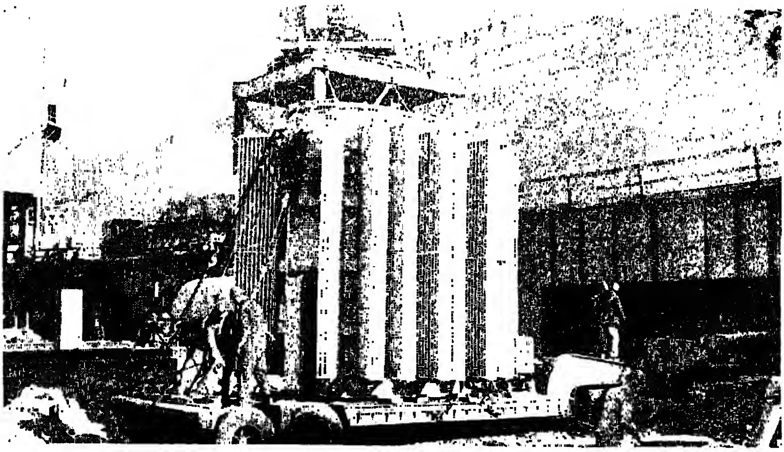


FIGURE 128.—*Main transformer.*

other footings were placed directly on the compacted earth fill. Figure 127 shows the foundation for a main transformer (fig. 128). The ducts in underground concrete envelopes, which carried the control leads from the powerhouse, led to two reinforced-concrete manholes in the switchyard, from which the control leads to the equipment were distributed in iron conduit. The galvanized steel structure was received completely fabricated and was erected by job forces (fig. 129).

The grounding system consists of one mat of bare copper cables laid in a bed of clay in the reservoir adjacent to the dam and a second mat located downstream from the switchyard below tailwater level. These two ground mats are connected to the switchyard surface grid, which in turn is connected to all switchyard equipment and steel structures.

CHANNEL AND SITE IMPROVEMENT

Channel improvement

The river channel downstream from the dam was graded and protected so that water from the spillway and the tailrace would have unobstructed discharge.

To provide a suitable outlet to the river channel for the water flowing through the turbines, a tailrace apron was excavated in natural rock, rising in a gradual slope from the bottom of the draft tube outlets to intersect the natural river bed.

The river banks, for a distance of several hundred feet below the dam, were graded and protected from wash with a layer of hand-placed rock riprap 2½ feet thick.

Site improvement

The major portion of the landscaping and site improvement was deferred for postwar construction. All construction areas, however, including borrow pits, road cuts, and construction yards, were graded and seeded.

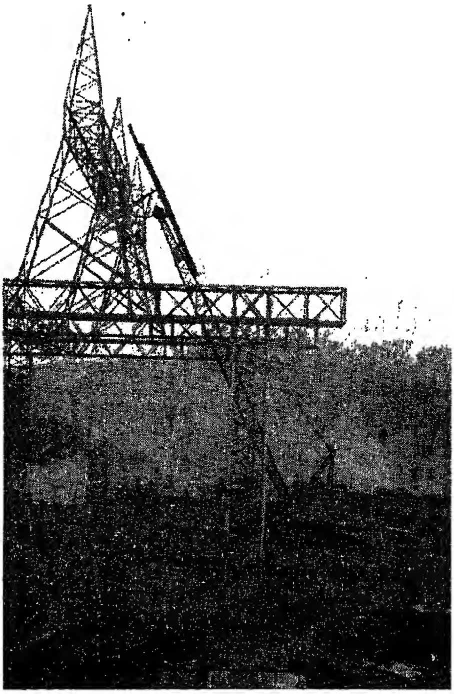


FIGURE 129.—*Erecting switchyard steel.*

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CHAPTER 6

RESERVOIR PREPARATION

Douglas Dam is located on the French Broad River, the largest tributary of the Tennessee River, approximately 32 miles above its mouth and 13 miles downstream from the town of Dandridge, Tenn. The impounded reservoir covers a rather flat valley averaging about one-half mile in width and extends into the foothills of the bordering ridges. The main river lake is 43 miles long, with sizable tributary arms in the valleys of the Nolichucky River, Flat Creek, McGuire Creek, Muddy Creek, and Indian Creek. The reservoir has an area, at surcharged level (top of dam gates), of more than 31,000 acres and lies in four Tennessee counties: Sevier, Jefferson, Cocke, and Hamblen.

Reservoir operations were based on a high-pressure schedule because of wartime conditions. In spite of rationing, priorities, and manpower problems the job was rushed to completion and closure of the dam was effected February 19,1943.

The land-acquisition program began immediately after authorization of the project. The program required completion of land-acquisition surveying and mapping, determining the extent of land requirements, and preparation of formal approvals (including legal tract descriptions) for the entire reservoir area within a period of 6 months. The land or rights in land acquired for this project comprise a total of 33,583 acres.

Clearing operations were started February 2, 1942, with clearing of the dam site, the quarry site, and other related clearance required for construction of the dam. A total of 5,182 acres was cleared—783.4 of bank clearing and 4,044 of regular clearing, and 355 acres tied down. The reservoir clearance program was officially completed February 17, 1943.

Five hundred and twenty-five families had to be removed in an unprecedented short period of 10 months from the date the dam was started. These families lived in the bottom lands and valleys that now form the Douglas Lake.

The power, telephone, and telegraph lines below the pool level were removed during the period between February 1942 and May 1943. A total of 121.9 miles of utility lines was removed from the reservoir.

Cemetery relocations totaled 2,449 graves removed. Highway and railroad construction involved 4.07 miles of access roads, 5.34 miles of state highways, 35.22 miles of county highways, 0.39 mile of streets in Dandridge, and 12.48 miles of tertiary roads.

SURVEYS AND MAPPING

The war emergency necessitated an unprecedented peak in TVA's construction activities and an increase in the survey and map produc-

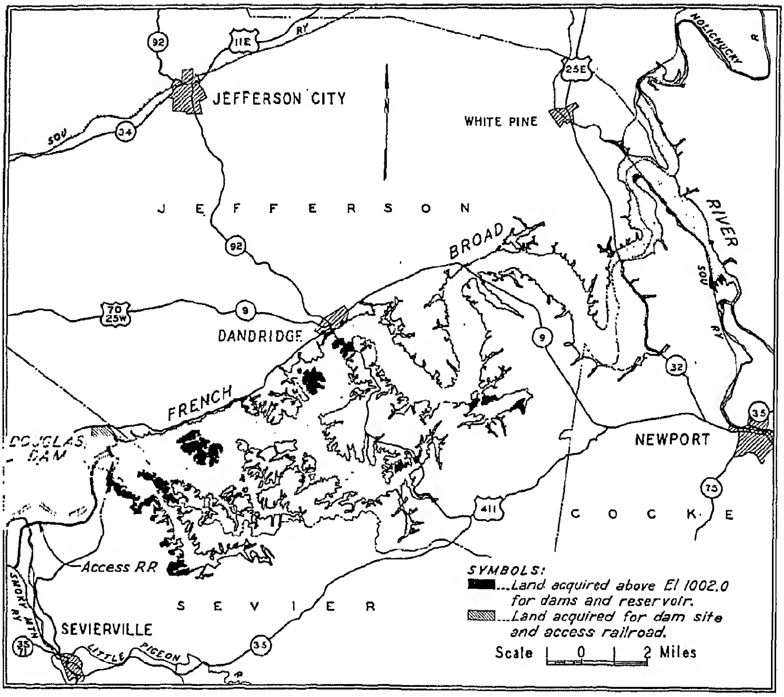

FIGURE 130.—*Reservoir boundary map.*

tion without sacrificing the standards of accuracy maintained on earlier projects. In anticipation of the exigency, extensive preliminary planning had been done so that surveys could be completed in the dam-site area before construction activities and in the reservoir region ahead of land acquisition, reservoir clearance, and other operations. Topographic maps of the reservoir area, scale 1: 24,000, had already been prepared under the valley mapping program. They proved invaluable for preliminary studies and planning and very helpful in expediting the more detailed surveys and mapping necessitated by construction of the reservoir.

The surveying and mapping activities embraced the following:

1. Land-ownership reconnaissance for 1,244 land tracts.
2. Property surveys and mapping covering 1,280 tracts, 72,039 acres.
3. Marking and mapping 565 miles of clearing contour.
4. Marking and mapping draw-down and early flooding contours.
5. Basic control surveys.
6. Surveys and maps for cemetery removal and relocation.
7. Topographic surveys and maps for special use, including the dam-site and saddle-dam-site areas.
8. Dam base line lay-outs.
9. Fee and easement boundary staking.

The main part of the field survey program was begun in February 1942 immediately following the project's authorization. To enable other TVA divisions with interdependent activities to meet exacting

schedules, it was necessary to finish the greater part of the work by June 1, and, except for permanent boundary marking, the surveying was completed by February 1943.

AREA MAPS

Planimetric map

Immediately following authorization of this project an urgent need developed for a medium-scale, accurate planimetric area map of the reservoir and vicinity. Such a map, showing important political boundaries, railroads, highways, drainage, schools, churches, cemeteries, trunk utility lines, and reservoir pool had been prepared and made available in July 1941.

The drainage and culture sheets of the TVA-USGS 1 inch=2,000 feet topographic sheets covering this area were assembled and compiled as a unit. To this base the 1,000-foot contour was transferred from an impression of the contour plate. The reservoir was screened with a stippled pattern, and names of counties, communities, railroads, drainage, churches, schools, cemeteries, highways, etc., were enlarged. After adding the title and borders, the composite map was photographed to a scale of 1 inch=1 mile. From photographic film, 11 by 30¼ inches, a positive film was then secured by contact printing. This preliminary map covered an area of approximately 290 square miles.

Upon completion of the land maps, a new area map, 22 by 60½ inches, was drafted on tracing cloth to a scale of 1 inch=one-half mile, which showed relocated highways, railroads, utilities, fee purchase and easement boundaries, the accurately mapped 1,002-foot pool contour, and other changes resulting from reservoir construction; basic information was transferred from the 1 inch=500 feet land maps. The tracing was then photographed to a scale of 1 inch=1 mile, with the reservoir screened and unscreened: and from each of the photographic negative films, 11 by 30¼ inches, positive contact films were secured; prints of this map were available with or without the pool screened.

Topographic map

During July 1941, a topographic area map at a scale of 1 inch=½ mile was prepared for the project by compilation from topographic sheets of the TVA-USGS 1 inch=2,000 feet quadrangles. The names of towns and counties were enlarged, the proposed dam and dikes were indicated, and the pool below the 1,000-foot contour was screened with a stipple pattern on this base. After the title and borders had been added, the composite was photographed to a scale of 1 inch=½ mile, and for use in obtaining economical reproductions, a positive film was made by contact.

BASIC CONTROL

Horizontal

The basic horizontal control network in the Douglas Reservoir area was established for and under the direction of the Tennessee Valley Authority by the Works Progress Administration in cooperation with the Tennessee Division of Geology. This control consisted of 209 miles of transit-tape traverse of second-order accuracy (1:10,000), each line originating and closing on United States Coast and Geodetic

Survey triangulation stations, or being run as a closed loop from such a station. Whenever practicable the traverse lines were routed along roads adjacent to and just above the future shore line. Triangulation ties across the river were made at frequent intervals to insure consistency in the traverse positions on both sides of the river and to shorten the traverse loops.

Monuments were set in pairs along the traverse route at about 1-mile intervals so that they could be used for both position and azimuth tie-ins. All intermediate stations were marked with angle irons. The monuments were precast concrete, 8 inches square at the bottom and 6 inches square at the top and 30 inches in length, weighing approximately 125 pounds. Each monument has a 3-inch circular bronze disk embedded in the top with "Tennessee Division of Geology—WPA" and the station designation stamped on the disk. The angle irons were 1 by 1 by 30 inches and were set with their tops projecting from 4 to 6 inches above the ground. "WPA" was stamped on one side and the county, line number, and station number were stamped on the other. All monuments were occupied by transit and included as stations in the line; no station was established by spur traverses.

The traverse system was computed by the Works Progress Administration in cooperation with the Tennessee Division of Geology on the plane coordinate grid system (Lambert projection) developed and published by the United States Coast and Geodetic Survey for the State of Tennessee. These computations were later checked and adjusted by the Tennessee Valley Authority.

Fixed-grid azimuths were established at a maximum distance of 40 instrument stations (which in general approximates a 5-mile interval) and at most junction points by observations on Polaris; the astronomic azimuths were converted to grid azimuths. All taping was done on bucks (portable tape supports), and the difference in elevation of the bucks was obtained by spirit leveling. Corrections computed for and applied to all field-taped distances included slope, temperature, tape calibration, and reduction to the sea-level-datum plane. Traverse closures were adjusted and distributed by the junction point method holding fixed the published positions of United States Coast and Geodetic Survey triangulation stations.

Much effective and economical use was made of supplemental horizontal control positions which had been previously established during the valley topographic-mapping program.

Vertical

The reservoir level-control net was run by the Works Progress Administration under a cooperative arrangement. The leveling was of third-order accuracy [1] and was routed through all monumented traverse stations. Each line originated and closed on first- or second-order levels previously established by the TVA in 1937 and 1938 in connection with the valley topographic-mapping program, or by the United States Coast and Geodetic Survey. All leveling was adjusted to the 1936 Southeastern Supplementary Adjustment Datum of the Coast and Geodetic Survey.

[1] Maximum closure of 0.05 foot times the square root of the length of line or circuit in miles.

AERIAL PHOTOGRAPHS

Aerial photographs covering 410 square miles of the reservoir area were furnished by Aero Service Corp. of Philadelphia on a contract basis. The original negatives were delivered to the TVA and additional prints and enlargements for surveying and mapping were made by TVA. The Zeiss P–10 precision mapping camera with a focal length of 3.907 inches was used at a flying altitude approximately 7,800 feet above ground, making the scale of the original negatives approximately 1:24,000 (1 inch =2,000 feet). A total of 260 photographs was required to cover the reservoir. The overlap of adjoining photographs in line of flight (east and west) was approximately 60 percent with an average overlap between adjoining flights (north and south) of approximately 40 percent.

CONTROL FOR MULTIPLEX BASE MAPS AND PHOTO SCALE DETERMINATION

Accurate scale planimetric base sheets and photographs are necessary in several surveying and mapping operations. It is necessary to establish horizontal and, if contours are to be mapped, vertical control on enough photo points to control the position and scale of the stereoscopic models in the construction of planimetric base sheets and to determine the scale of aerial photographs. Positions and elevations were established on 74 photo points. After the accurate-scale planimetric base sheets had been completed (by multiplex) they were used to determine the scale of each aerial-photograph negative by comparison of scaled distances between identifiable points. This method of photo scale determination also simplified the computations for determining tilt in the aerial photographs, however, most of the photographs for the Douglas project had tilts so small they could be ignored. In the occasional case where sizable tilt was present, its amount and direction were easily determined. Scale and tilt values were supplied to the aerial photograph laboratory where enlargements or reductions from the negatives were made.

NEW LARGE-SCALE MULTIPLEX BASE MAPS

The gratifying results obtained on the TVA's Cherokee project and Hiwassee projects in the use of accurate large-scale planimetrics as a base for plane-table surveys instead of enlarged-ratioed photographs led to the use of base sheets prepared by multiplex methods [2] on the Douglas project. Adoption of this plan was an important factor in completing the survey and mapping program on schedule. The sheets were prepared on a scale of 1:6,000 (1 inch=500 feet) from the specially flown photographs and showed accurately the location of such features as field boundaries, fence lines, hedgerows, ridge lines, drainage features, roads, trails, buildings, wooded and cleared areas, etc. A total of 17 base sheets covering 112 square miles was required for the project. In addition, detailed topographic maps of the dam site and saddle dam areas were made on a scale of 1

[2] Tennessee Valley Authority Technical Report No. 5, *The Hiwassee Valley Projects*, vol. 2, "The Apalachia, Ocoee No. 3, Nottely, and Chatuge Projects," pp. 499 and 500, 1947.

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inch=500 feet by multiplex methods, which resulted in a real saving of time and money.

ENGINEERING FOR LAND ACQUISITION

The property surveying and mapping program consisted of two principal parts. The first part is the land-acquisition surveys, which are sufficiently complete and accurate for use in purchasing land to be later merged into one large reservoir tract or reservation, but are not intended to serve as a basis for reestablishing original tract boundaries. Since most of the property lines between individual tracts are to be inundated and obliterated, it is not necessary to retrace or recover them after the reservoir fills. It is necessary, however, to provide property surveys and plats which permit acquisition of the tracts to be accomplished legally, fairly, and efficiently. The general term "acquisition" as used here includes appraisal, abstracting, title examination, description, and procurement by purchase and/or condemnation proceedings.

The second part of the property surveying program comprises the transit-tape measuring and the monumenting of the government reservation boundary line. This is the line of demarcation between Government-owned and privately owned land, and the ability to retrace or relocate its corners precisely at some later date is essential. Also, its visibility on the ground facilitates policing, fencing, clearing, leasing, cultivating, erecting buildings, other administrative and managerial functions, and reduces the tendency of adjoining owners to encroach on the Government reservation.

Property reconnaissance

The first operation in the property surveying and mapping program was the preparation of a preliminary property-ownership index map, which served as a base for deed copying and deed record notes and in addition was helpful in the planning and execution of the property surveys and land mapping.

Property-ownership information was obtained in the field by surveyors who marked the data on photographs enlarged to the scale of 1:10,000 (1 inch=833⅓ feet). Each property owner or occupant was contacted to determine the approximate boundaries of his tract. Corner locations were pointed out in the field to the surveyor and, where definite, were painted red so they could be easily found when the actual property surveys were made. The corners were then spotted on the photograph and marked and described in ink. Property lines joining these corners were then sketched in, the surveyor noting the owner's name and the book and page number of recorded deeds. This information was recorded in duplicating notebooks so the original pages could be removed by the deed copier. If the deed was recorded but not in the possession of the occupants, the approximate date of recording was obtained to facilitate a later search in the county register's office. Unrecorded deeds were copied in the field and turned in to the deed copier for typing. The surveyor assigned each deed a number and a letter prefix which designated the county and then inked the owner's name and deed number (or numbers) on the photograph. Property lines and ownership data were secured for each tract touched by the 1,007 contour, the acquisition guide, and all the adjoining tracts. In

some few peninsula areas where the acquisition policy had not been definitely established, property-ownership information was obtained over the entire area. The photographs were then projected onto prints of the 7½-minute quadrangle topographic maps, scale 1 inch=2,000 feet. After the proposed pool contour had been interpolated and accentuated in ink, the area below pool was shaded by a screen pattern. A positive film of each quadrangle map was then made by photographic processes in order that contact prints could be secured.

These ownership index maps were extensively used in planning and scheduling work, in preparing preliminary cost estimates, and in preliminary abstract work. The original field reconnaissance photographs, together with the index maps, were later furnished to the property surveyor to be used as a guide in the more accurate location of lines and corners. To supplement the information described above, a list of property owners' names and addresses was compiled for use in indexing and abstracting. Later, a second list of names and addresses was prepared, listing the owners of property tracts to be affected by possible early flooding caused by cofferdam flow restriction.

Deed copying

A new method of deed copying was employed during the period of peak production; a portable photostat machine was used to augment the usual typing method. Deed copying by photostat proved very satisfactory as it eliminated the job of proofreading, and words or figures which were not clear on a damaged original could be correctly interpreted on the photostat copy while the deeds were being plotted.

As soon as the ownership reconnaissance data became available, employees stationed at each county seat copied the recorded deeds or other instruments of conveyance for each tract, as well as all recorded plats.

After the deeds had been copied, they were plotted to a scale of 1 inch=500 feet on vellum (if plottable) and compared with the outlines of the tracts shown on the reconnaissance ownership photographs. In cases of major discrepancies, the deed copying was checked and if no error was discovered the field reconnaissance was checked before forwarding to the property surveyor.

Field procedures on property surveys

For the purpose of determining the appropriate surveying methods, property tracts were divided according to size into three general classifications:

1. Farm tracts from about 10 acres up, these being surveyed almost entirely by the use of planimetric-base plane-table sheets on a scale of 1:6000 (1 inch=500 feet).
2. Small rural tracts, ranging in size from about one-half acre to 10 acres, usually surveyed by plane table on white paper on scale of 1: 2400 (1 inch=200 feet). Traverse stations with azimuth ties were shown where available or two or more property corners appearing on the 1 inch=500 feet sheets were tied in so that these small tracts could be plotted in their correct positions on the finished land maps.
3. City lots or subdivison lots were either surveyed by transit-tape or plane-table methods, using as a base the large scale detail topographic surveys generally prepared for towns and communities in or surrounding the reservoir area. It is found that often in making plane-table surveys of towns or subdivisions, good use can be made of reproductions of recorded plats photographed to the same scale as the property survey, provided the originals are accurate.

A total of 1,280 tracts, covering 72,042 acres, was surveyed and mapped by these three methods. The deed descriptions in the reservoir and adjoining area were, in general, very good as compared with previous reservoirs. Because of the high state of cultivation, the property lines were usually well defined and only in a very few cases were they involved in dispute.

Multiplex base sheets

Plane-table sheets were first prepared in the office by projecting the multiplex planimetric base sheets, scale 1:6000, to double mounted sheets 20 by 25 inches in size (inside working limits). The limits of each finished land map had been previously determined from reconnaissance ownership maps, and the projection was made so that a plane-table sheet covered the entire area which was to be shown on the finished land map with an approximate inch overedge of culture to allow for possible discrepancies in reconnaissance ownership plotting. All horizontal control stations were then plotted by coordinates.

The field surveyor was supplied with the plane-table sheet, the property reconnaissance photographs, copies of the deeds, and all necessary surveying equipment. The owner or occupant of most tracts was again contacted for a final check on his property corners and boundary lines. In the case of lost or destroyed corners, the adjoining owners affected were called together at one time to determine from them jointly their common corners and lines. If all interested owners agreed, and search on the ground did not disclose any conflicting evidence, these corners were plotted in their proper locations on the plane-table sheet by deed and then marked on the ground. Where the owners could not be contacted or did not know where the corners had been located originally, the deed bearings and distances from other located corners were plotted and adjusted, and the corner located in the same manner. Stakes were set at these plotted corners for the owners' information and also to make them easily recoverable in case they became corners on the Government reservation boundary. Where the property corners and lines were already shown on the plane-table sheet (projected from the multiplex base), as was often the case with fence intersections and fence lines in cleared areas or with streams, roads, and lanes, the plotting was merely a matter of emphasizing the lines and intersections already shown. About 50 percent of the property corners and lines in the Douglas Reservoir area were clearly identifiable on the photographs and showed up in the multiplex model. All boundary courses less than 500 feet in length were taped in the field and held fixed during the later plotting of the land maps in the drafting room. Where the property corners and lines were not directly identifiable on the plane-table sheets they were plotted by running a conventional plane-table traverse originating from a nearby identifiable mapped point or control station. The traverse would then be routed through the desired property corner or corners and carried forward to close on another clearly identifiable point or control station. This type of plane-table traverse work was used principally where property corners were located in dense woods or other areas where identification was difficult.

As a part of the field survey work the surveyor delineated on the plane-table sheet all the features which were to be shown on the final map, such as roads, lanes, trails, buildings, orchards, woods, ridges,

bridges, culverts, streams, canals, millraces, railroads, power and telephone lines, and similar features. He also lettered on the plane-table sheet the owner's name and deed number and all necessary explanatory notes describing each property corner and property line. All plane-table sheets were carefully checked for clearness, accuracy, and completeness, and returned to the field for correction. This facilitated the drafting procedure and resulted in a considerable saving in time since it was seldom necessary, after this check had been made, to return the sheet from the drafting room to the field for correction.

Contour mapping

The 1,002-foot pool contour had been previously marked with white paint on the base of trees in wooded areas and with white stakes through cleared and brushy areas. This contour was plotted directly on aerial photographs (scale 1:6000) by field inspection where sufficient cultural detail existed nearby to permit positive identification and by plane-table traverse in woods and open fields. The 1,007-foot contour, which was used as a general acquisition guide, was located and plotted at the same time. Plane-table traverse used for contour plotting in open or wooded areas began and ended on clearly identifiable photographic points. The total shore line along which these contours were surveyed and plotted is 565 miles. In addition to the pool and acquisition guide contours, the 930- and 910-foot contours were mapped by the same methods, but with a somewhat lesser degree of accuracy. The 930-foot contour was the lower limit of clearing, and the 910-foot contour was the elevation of possible early flooding after the construction of the early stage cofferdam. One hundred and twenty-eight miles of 930-foot contour and 82 miles of 910-foot contour was mapped.

Land acquisition maps

The drafting of land acquisition maps began immediately after the survey work was started and was completed in June 1942. With six exceptions, all maps were prepared on a scale of 1 inch=500 feet with insets of small tracts on larger scales. The six exceptions cover the town of Dandridge and the villages of Shady Grove and Rankin, which were mapped on the scale of 1 inch=100 feet, and the Pleasant Hill Cemetery, which was mapped on a scale of 1 inch=20 feet.

Upon completion of the field property surveys, the plane-table sheets and aerial photographs, together with pertinent deeds and other supporting data such as subdivision plats, utility and highway right-of-way maps, etc., were delivered to the cartographic section. All tract boundaries, ownerships, subdivisions, etc., were again checked against deeds and other supporting data, and where the surveyor had not accounted for discrepancies the material was returned for a field check.

Contours which had been mapped on photographs, after examination under the stereoscope for discrepancies, were transferred to the field plane-table sheets with a vertical map projector. After the field sheets had been checked they were traced in ink on 22- by 34-inch cloth sheets. Copies of this series of first-stage land maps were then used for the designation of easement and fee purchase boundary lines. Prints of the land map showing the easement and fee purchase information were then sent to the field in order that the lines could be surveyed and staked on the ground. Upon completion, the field survey

notes, together with the copy of each land map used and marked up by the field organization, were returned to the computing office where bearings and distances along the purchase line and the coordinates of all corners were computed, all on the State plane coordinate system. This information was then added in ink to the tracing.

The acreage of each individual tract, except those of regular shape, was measured by planimeter, the regular tracts such as parallelograms or triangles being computed from scaled or measured distances. An appraisal plat of each tract or partial tract affected by the easement or purchase line was also prepared. The acreage measurements and the drafting of appraisal plats were completed after the final information on the purchase boundary had been received from the field. Bearings and distances on all tracts affected by fee and easement purchase, with the exception of those previously measured in the field, were scaled on the plane-table sheets and inked on the land-map tracings. Acreage measurements, broken down into such items as cleared, wooded, water, and miscellaneous, were tabulated. On the completion of all steps outlined above, a description was obtained of the fee and easement tracts to be acquired.

PERMANENT MARKING AND SURVEYING OF RESERVATION BOUNDARY LINE

Reservation boundary marking and surveys

The practice of staking the boundary in advance of the preparation of the tract descriptions and acquisitions was followed on the Douglas project. This proved to be of considerable advantage to the land buyers since they could more easily negotiate with the owners when able to point out on the ground the exact location of the severance or easement lines. A further advantage of using the transit-tape measured bearings and distances along this outer boundary line in the deed descriptions was the elimination of differences between the deeds taken and final reservation maps, on which transit and tape-measured boundary corners are always shown.

The locations of established severance lines were indicated on advance copies of the land maps, and a surveyor, using this map as a guide, set a semipermanent marker at each corner of the boundary, adjusting the exact location of the line to take advantage of, and follow, any nearby natural boundaries, and to exclude or include any specified buildings and other improvements. These corners were then tied in by transit-tape traverse, which originated and closed on the reservoir traverse control stations. The computed bearings and distances of the boundary line between corners were shown on the land maps and used in the tract descriptions. Where easement purchase was used instead of fee-simple purchase, the easement contour was marked by orange-painted stakes of a semipermanent nature. After staking, this easement line was checked on the land maps by plane table and/or inspection for discrepancies in the original mapping or projection to the land maps.

Marking the boundary line

As the final boundary surveys were run, corners which could be immediately established were coordinated and marked by 1- by 1- by 24-inch angle irons. Those that could be only tentatively estab-

lished at the time of the original survey, pending completion of computations, were temporarily marked, the final corners being later established by short azimuth and distance measurements (turn-outs) from the temporary corners. The final marking of the boundary will be accomplished by setting painted steel fence posts at each corner location, except that at approximately every mile, two adjoining and intervisible corners will be marked by the usual concrete corner posts with inscribed bronze disks. Also, on each isolated fee-purchase tract two adjacent corners are marked by concrete corner posts. On the fee-purchase line within the town of Dandridge, every corner is marked by a concrete corner post. The lines, as distinguished from corners, will be marked by painting line and witness trees in wooded areas, and by intervisible wooden posts where the boundary crosses cleared land. All these line markers will be selected and located in such a way that from each mark the adjacent mark in both directions will be visible.

Reservation maps

The reservation maps indicate accurately the fee and easement boundaries, boundary corners, and the conditions existing within the reservoir areas after completion of the dam and reservoir construction. They are designed primarily for boundary data records to be filed in the appropriate county courthouses, for regional planning studies, and to facilitate the management and operation of the reservoir properties.

The maps are drafted in ink on tracing cloth sheets 22 by 34 inches on a scale of 1 inch=500 feet, and follow substantially the sheet lay-out of the land-acquisition maps. Reproductions on that scale are available in each of three stages. Multilith copies on a scale of 1 inch=1,000 feet (sheet size 11 by 17 inches) are also available for the third or C-stage map.

In preparing the original tracing, the Tennessee State rectangular grid projection is plotted on each sheet and the reservation boundary corners are then plotted by coordinates. Land-map features shown on the reservation maps are traced directly, adjusted slightly where necessary to fit the plotted boundary data and other control. The dam, powerhouse, and other reservoir structures are then added, along with relocated highways, railroads, and transmission lines. The information is plotted and traced progressively in the three stages, A, B, and C, a transparent reproduction (scale 1 inch=500 feet) being obtained on the completion of each stage, from which contact prints may be obtained as needed.

Stage A shows the reservation boundary with corners, the reservoir shore line, the easement contours, existing roads and railroads, streams, buildings, timber cover, river improvements, boat docks, operating bases, etc.

Stage B shows, in addition to information indicated on the stage A maps, the corner identification numbers and the bearings and distances of the boundary line tangents computed on the State rectangular grid projection.

Stage C includes the addition of former individual tract boundaries between the reservoir pool and the reservation boundary lines. The tract numbers and the names of former owners from whom the various tracts were purchased were also added. Reproductions of the C-stage

maps may be obtained either on the drafted scale 1 inch=500 feet or on a scale of 1 inch=1,000 feet. A tabulated list of the boundary coordinates, computed on the State rectangular grid projection, is shown on the 1-inch=1,000-foot scale reproductions but not on the 1-inch=500-foot prints.

ENGINEERING FOR RESERVOIR CLEARING AND RIM TREATMENT

Pool contour marking

The upper limit for complete clearance of timber, brush, and other materials from the inundated area was set at elevation 1,002. To insure complete clearance of all fallen material, elevation 930 (5 feet below the draw-down level) was selected as the lower clearing limit. Elevation 910 was considered as the probable maximum to be reached by backwater as the result of the early-stage cofferdam construction. These three contours were marked with levels of fourth-order accuracy, originating and closing on reservoir-level-control third-order benchmarks. Five hundred and sixty-five miles of pool contour (elevation 1,002) was marked; 492 miles along the main shore and 73 miles around islands. One hundred and twenty-eight miles of lower clearing contour (elevation 930) and 82 miles of early flooding contour (elevation 910) were marked.

In wooded areas a white band, approximately 2 inches wide, was painted on the trunks of trees, the top of the band being the clearing elevation. Through cleared areas the line was marked by white stakes at the correct elevation on the ground and by paint marks on fence posts, buildings, and other structures when possible. Marks were always located so as to be intervisible, but were of necessity more closely spaced in wooded areas than on cleared land. In wooded areas "fore and aft" paint splotches were placed about 5 feet high on each marked tree to facilitate finding and identification of the marked line. The lower clearing contour was marked in a similar manner, except that the levels were of somewhat lower order and red paint was used instead of white.

Marginal marking for shore line clearing

Along the wooded portion of the shore line, the narrow strip of terrain immediately adjacent to and above the clearing contour was marked in certain areas for partial or complete clearing in accordance with TVA specifications. In areas where bank caving from wave action was expected, complete clearing was extended from 10 to 20 linear feet back of the 1,002-pool contour, the width of the cleared margin depending on the steepness of bank slope and the species and condition of the trees. The outside limit of this 10- to 20-foot-wide strip was indicated by marking the trees along its limits with splotches of red paint; this work was performed by a crew of two men immediately preceding the clearing operations. The previously marked clearing contour in the wooded areas was inspected, and any obliterated or defective markings were freshened or restored.

Rebrushing contour marking

During the late fall of 1942, after the growing season was over, the 992-elevation contour was run out and marked on the ground through all brush areas and cultivated fields. This was for the purpose of

marking the lower limit of the area (between the 992 and 1,002 contours) to be rebrushed and cleared of flotage. The 992 contour was traced out by fourth-order leveling, the marking was done by tying small strips of yellow flagging on brush, cornstalks, and such, directly above elevation 992 on the ground. At the same time, the 1,002-pool contour was remarked or repainted through these brush and cleared areas wherever it had become obliterated or dimmed. Approximately 459 miles of the 992 contour was marked, and 36 miles of the 1,002 contour was retraced or repainted.

Timber clearing estimates

Detailed and accurate estimates were prepared semimonthly. These gave the amount and types of clearing and other work performed during each half-month period by each clearing unit. The areas cleared and burned were usually planimetered from the land maps or the contour-mapping aerial photographs, but transit-tape surveys with computed areas were made of many small or critical areas. Also, proper allowance had to be made for such items as scattered trees and hedgerows. The clearing estimates and the progress status of each clearing operation were shown in detail on copies of the land maps. The estimates covered a total of 4,799 acres of regular clearing and burning, and 88 linear miles of bank clearing.

Drainage surveys

Engineering work was done on 17 drainage projects. These projects were for the purpose of draining sink holes and similar areas located in the zone between flood stage and the minimum draw-down elevation. The preliminary engineering work on each tentative project included preliminary line, profile, or topographic surveys, numerous probings for rock depths, plotting the results, and preparing a preliminary estimate. Each such project was then reviewed before construction was authorized. On each authorized project the final engineering work included laying out and staking on the ground, and supplying construction data for excavation work. On completion of each project a final survey and/or inspection was made, and correct excavation quantities were computed. Of the 17 drainage projects surveyed, 9 were constructed and 8 were abandoned.

NAVIGATION MAPS

Navigation maps of the Douglas Reservoir area were prepared. Since this project is located on the French Broad River, a tributary of the Tennessee, and only a limited amount of commercial navigation is anticipated, the charts were prepared similar to those for the Cherokee project. Four-color lithographic reproductions are now available in three sheets on a scale of 1 inch=½ mile. They show roads, railroads, political subdivisions, the Tennessee Valley Authority purchase and easement boundaries, buildings, wooded areas, navigation aids, and the elevation 1,002, 960, and 940 contours, with areas between these contours indicated by varying shades of blue.

Composite lithographic prints of the culture and drainage plates (culture in black, drainage in blue) of the 1:24,000 scale topographic quadrangle maps prepared under the valley-wide topographic mapping program form the mapping base. To this base were added the 1,002 contour, obtained from the land-acquisition maps, and the 960-

and 940-foot contours taken from the valley topographic maps. Certain place names and cultural information were enlarged, and the navigation information was added. All obsolete information was deleted. The base maps were made into composites covering the desired navigation sheet area and photographed. Three blue-line prints of each chart were then obtained on metal-mounted sensitized paper to a scale of 1 inch=2,000 feet. These blue-line impressions were then inked—one for each color plate, red, blue, and green. Each of the color separation sheets, including the original culture base, was photographed to a scale of 1 inch=½ mile. Next, press plates were made and the final charts were reproduced in four colors by lithographic processes in the TVA's reproduction shop.

RELOCATION SURVEYS

Cemetery surveys

All cemeteries within the reservoir area were surveyed and plotted on a scale of 1 inch=20 feet, with 1- and 2-foot contours. Cemeteries were first cleared of underbrush and each grave marked by a stake with an identifying number assigned. Each grave was then plotted on the plat in its proper position, using symbols to indicate the condition of the grave, type of markers, etc. Other useful data such as the name and nearest relative of each person buried was secured at the time. A total of 69 cemeteries (5,108 graves) was surveyed. The reinterment cemeteries were staked out by plane table from a plat on a scale of 1 inch=20 feet.

Cemetery mapping

Individual record plats were prepared (scale, 1 inch=20 feet) for all cemeteries requiring either disinterments or reinterments. Each grave was numbered on the plat and entered in a permanent record with the name of the deceased. Plats were made of 69 disinterment cemeteries (5,108 graves) and 93 plats were made of 54 reinterment cemeteries (2,449 graves).

Utility surveys

All communication lines, power lines, and other utility structures affected by the reservoir were surveyed and plotted. All poles and structures were first located on the 1 inch=500 feet property survey sheets by the property surveyor. Positive photostats were then made of these sheets and they were returned to the field where elevations of the ground at each pole or structure were secured by alidade and plane table. A total of 41 projects, including 87 miles of lines, was surveyed.

MISCELLANEOUS AND SPECIAL SURVEYS

Dam base line layout and monumenting

A local construction grid system was adopted for the layout of the Douglas Dam base line and reference lines. The base line was made the X axis with stationing increasing both downstream and upstream along the Y axis, which was located at right angles to the base line, approximately 1,200 feet northwest of the center line of the river. Station numbering along the X axis (base line) extended south-

easterly and northwesterly from the Y axis. Thus, each monument or point was referenced by two station numbers which had a direct relation to all other points or monuments in the layout.

First-order control methods were used in establishing the layout. Four monuments were set on the base line, two on each end approximately 150 feet apart and beyond the construction limits. Three offset ranges were also requested, one 400 feet downstream and two upstream at 400 and 800 feet from the dam axis. The station numbering of the base line was established by first-order triangulation and chaining. Perpendicular offset lines were then established, all angles being read with a 20-second repeating theodolite or a 1-second direction theodolite. Twelve readings were made on each angle, six with the telescope direct and six with the telescope inverted, the mean of the twelve readings being the measure of the angle. Offset chaining of first-order accuracy was done along these perpendiculars to establish the correct position of the offset ranges.

In addition to the four monuments set on the base line, four were set on the 400-foot downstream range, six on the 400-foot upstream range, and three on the 800-foot upstream range. Four additional off-range monuments were set for preserving the stationing along the base line. The positions of all monumented points then were checked by precise triangulation. After all chaining and triangulation had been computed and adjusted, the final positions were indicated by punch marks on the monuments. Finally, the layout was tied in to the state coordinate system (Tennessee Lambert projection) by third-order traverse run from the reservoir horizontal control net.

To maintain a high degree of accuracy for the control of construction, level work of first-order accuracy was used in establishing the elevation of monuments, even though the benchmarks were on a second order net.

A total of 21 monuments was set in the dam site area. All were concreted in place with a standard TVA bronze tablet embedded in the top. Each monument was about 1 foot in diameter at the top and approximately 3½ feet long, projecting approximately 2 inches above the ground surface. The horizontal control point was precisely indicated on each tablet by a small punch mark. A substantial wooden fence was built around each monument for protection, and the designation and elevation of the monument was painted on the fence.

Silt range surveys

Surveys were made to establish 50 ranges for the future measuring of silt deposits in the reservoir area, the ranges being marked at each end with concrete monuments. The horizontal position and elevation of each monument was established by traverse and levels of third-order accuracy, and a profile was run along each range. These profiles were plotted, and a periodic check will be made by soundings to determine the amount of silt deposits.

Surveys for tributary channels and boat bases

Engineering work was performed for establishing and marking small boat channels along the tributary streams. This work consisted mainly of determining and staking the locations for the channel markers and the preparation of estimates of grading quantities and

the bills of material for the purchase of the markers. In small streams and canals the small boat channel routes were marked on the left side only (facing downstream) by posts planted 3 feet in the ground and of such height that about 2 feet would project above the water surface at full pool. Large-scale topographic and other detailed information

TABLE 35.—*Summary of surveying*

Basic control:			*Miles*
Traverse (WPA), third-order accuracy			209
Levels, third-order accuracy			209
Aerial photographs:			*Square miles*
Area photographed			410
			Photographs
Number of photographs			260
Enlargements to 1 inch=500-foot scale			249
Enlargements to 1 inch=833-foot scale			249
Engineering for land acquisition:		*Acres*	*Tracts*
Property ownership reconnaissance		82, 165	1, 244
Land tracts surveyed		72, 039	1, 280
			Deeds
Deeds copied			2, 065
		Elevation	*Miles*
Contours surveyed and plotted on aerial photographs:		1, 007	612
		1, 002	565
		930	128
		910	82
Land maps drawn:	*Maps*	*Acres*	*Tracts*
Scale 1 inch=500 feet	53	71, 870	1, 079
Scale 1 inch=100 feet	5	169	201
Scale 1 inch=20 feet	1	3	1
Permanent marking and surveying of reservation boundary line:		*Miles*	*Corners coordinated*
Boundary traversed by transit tape		35	575
Elevation 1007 easement contour staked		405	-----
			Plats
Reservation plats drawn			None
Scale 1 inch=500 feet			[1] 55
Scale 1 inch=100 feet			[1] 5
Engineering for reservoir clearing and rim treatment:			*Miles*
Elevation 1002 clearing contour marked			[2] 565
Marking for marginal clearing			159
Elevation 930 draw-down contour marked			128
Elevation 910 early flooding contour marked			82
Elevation 992 rebrushing contour marked			459
Elevation 1002 contour, remarking			36
			Acres
Clearing estimates			4, 799
			Projects
Preliminary drainage surveys			17
Final drainage layout surveys			9
Cemetery relocation surveys:		*Cemeteries*	*Graves*
Surveyed and mapped		69	5, 108
Removal and remain agreements secured			2, 589
Maps drawn:		*Maps*	
Disinterment—scale 1 inch=20 feet		69	5, 108
Reinterment—scale 1 inch=20 feet		93	2, 449
Utility relocation surveys:		*Miles*	*Projects*
Surveyed		87	41

[1] Estimated totals.
[2] 492 miles main shore line, 73 miles islands.

for malaria control boat bases, for canals, and for other proposed navigation improvements were made as requested.

Special topographic surveys

Numerous large-scale topographic surveys and maps were completed at various sites within the reservoir area for a variety of purposes,

and mapping activities

	Monuments	Feet
Dam site layout: axis layout and monumenting [3]	21	10, 000
Silt range surveys:		*Miles*
Monuments set	99	-------
Levels to monuments	99	55
Traverse to monuments	99	41
	Ranges	
Profiles	50	-------
Soundings	38	-------

Topographic maps:	Number of sheets	Scale	Contour interval	Area mapped acres
Dam site	7	1 inch=100 feet	2 feet, 4 feet	251
Do	1	1 inch=200 feet	10 feet	123
Do	4	1 inch=500 feet	10 feet	3, 537
Dike site	11	1 inch=100 feet	2 feet	182
Do	7	1 inch=200 feet	4 feet	730
Dandridge flowage	4	1 inch=100 feet	1 foot, 2 feet	74
French Broad Baptist Church and vicinity	1	1 inch=20 feet	2 feet	3
Boat harbor No. 1	1	1 inch=50 feet	1 foot, 2 feet	1
Boat harbor No. 2	1	1 inch=50 feet	1 foot, 2 feet	5
Trailer camp site	1	1 inch=100 feet	2 feet	38
Dam site coast guard base	1	1 inch=100 feet	2 feet, 4 feet	17

Miscellaneous surveys:
- Soundings and probings of 19 ranges in cofferdam and bridge crossing area at dam site.
- Seven United States Coast and Geodetic Survey monuments reset and second-order levels run over them to replace monuments that would be destroyed by construction or flooding.
- Surveys of navigation hazards in reservoir such as silos, bridges, bridge piers, and other obstacles.
- Plane-table check of 1 inch=500 feet multiplex topography in dam-site and saddle-dam area.

Miscellaneous maps:
- Utility relocation:
  - Index of lines in reservoir, scale 1 inch=½ mile.
  - Index of lines in reservoir, scale 1 inch=1 mile.
  - Index of relocated lines in reservoir, scale 1 inch= 1 mile.
- Malaria control:
  - Malaria control map, scale 1 inch=2,000 feet.
  - Malaria control map, scale 1 inch=8,000 feet.
  - Index of drainage projects, scale 1 inch=1 mile.
  - Construction layout for two boat bases, scale 1 inch=50 feet.

Composite map of dam-site area, scale 1 inch=1,000 feet, made of four sheets (scale 1 inch=500 feet) of multiplex base maps showing strip topography of dam-site and saddle-dam area corrected in critical areas by plane-table topography.
Silt range index map, scale 1 inch=1 mile.
Land map index map, scale 1 inch=1 mile.
Cemetery index map, scale 1 inch=1 mile.
Control index map, scale 1 inch=½ mile.
Map showing dam axis layout and monumenting, scale 1 inch=200 feet.

[3] First-order chaining.

all by plane table. Briefly summarized according to the mapping scale, the acreages covered are as follows:

Scale:	*Acres*
1 inch=20 feet	3
1 inch=50 feet	6
1 inch=100 feet	563
1 inch=200 feet	671

Utility relocation maps

No special plats were prepared of the utility structures affected by the reservoir. However, their position, ownership, and other pertinent data were shown on the Douglas land-acquisition maps. In addition, approximately 21 exhibit drawings for use in conveying easements and right-of-way for the utility relocations were made. Approximately 15 miscellaneous exhibit maps for use in contracts, etc., were drawn or prepared by compilation and reproduction.

Miscellaneous maps

For this project, various types and kinds of maps and plats were prepared, such as index maps, condemnation plats, etc. Among these special maps were two malaria control maps, scale 1 inch=2,000 feet, and one malaria control map, scale 1 inch=8,000 feet, covering the reservoir and vicinity; the latter was a photographically reduced film of a composite of the first two.

LAND PURCHASE CONTROL

The land purchase program began immediately after authorization of the Douglas project, January 30, 1942. It was necessary to complete land acquisition surveying and mapping, determine the extent of land requirements, and prepare formal approvals (including legal tract descriptions) for an entire reservoir area within a period of 6 months. With the exception of the usual clean-up work and curative problems, the job was actually completed in 5 months.

For the dam site and reservoir proper, excluding rights-of-way for appurtenant construction and temporary construction rights, approvals were issued for the acquisition of fee title or flowage easements on approximately 1,000 tracts totaling 33,000 acres.

On the Douglas project the land acquisition policy provided that the purchase of lands for reservoir purposes should be limited to the minimum appropriate for the project. In general, lands lying above the zone of reservoir fluctuation, designated elevation 1002 (plus appropriate backwater considerations), were not to be purchased in fee simple. At the same time, however, provision was made specifically for additional purchases in fee simple for certain clearly designated reasons, as follows:

> It is hereby declared to be the policy of the Board (TVA) to limit the purchase of land for reservoir purposes to the minimum appropriate for the particular project. In general, land lying above the zone of reservoir fluctuation shall not be purchased in fee simple, except where it is found that such purchase is necessary or expedient—
>
> (a) to avoid impracticable severance, isolation of property, or disproportionate road relocation costs;
>
> (b) to protect the reservoir or the property, equipment, and interests of the TVA or the United States;
>
> (c) to take care of authorized programs which are incidental to the general construction programs.

In other cases where it is is found necessary or expedient to purchase any interest in such lands in order to discharge a legal liability for intermittent flooding or other damage resulting from the construction or operation of the reservoir, or in order to permit the TVA to carry on operations essential to the construction or operation of the reservoir, such purchases whenever practicable shall be by appropriate easements, which shall safeguard the interests of the TVA and the United States.

To avoid construction of substitute roads which would have cost several times the value of the lands to be served, contractual arrangements were entered into with Jefferson County whereby the TVA agreed to indemnify the county against any and all liability for damages claimed by individual owners for complete or partial loss of access facilities. Under this procedure, although certain of the more important through roads were constructed by the TVA, rather large areas on peninsulas and along the rim of the reservoir were left completely isolated from road access. To avoid acquiring this isolated land, the TVA purchased from the owners damage releases intended to relieve both the TVA and the county of further liability. It is estimated that in Jefferson County, which contains approximately three-fourths of the reservoir, access damage releases were secured on about 9,000 acres.

As a result of the restrictions imposed in connection with acquisition of fee title, only about 2,400 acres of land above the surcharged pool level was approved for fee purchase. Most of this acreage is composed of the dam site area and large islands formed by the lake; the remainder was principally areas required for construction purposes, the access railroad, and departmental programs.

Since a large percentage of the reservoir rim is rough wooded hillsides, the costs of road replacements were, in many cases, prohibitive, particularly on the south side of the river. It was necessary, therefore, to secure access damage releases for a cash consideration, either as a supplement to the flowage easement or through a separate acquisition if no part of the property would be flooded.

Access questions became a major consideration in the acquisition program. Since the purchase of flowage easements rather than fee title on lands above the surcharged reservoir was mandatory, as a general rule, discretionary variations in types of acquisition employed were very limited. It was necessary, however, to follow the procedures worked out and developed on previous projects in the processing of land tracts affected by the reservoir. Detail field inspections were made, and in addition to noting the means of access used by each property and the extent to which it would be affected, information on farm operating methods, land usage, and the approximate value of improvements was shown on preliminary copies of the land maps. Justification for tertiary road construction was determined on the basis of comparative costs and the agricultural possibilities of the lands involved.

The ordinary date of possession for reservoir lands on the Douglas project was December 1, 1942, providing sufficient time for completion of the reservoir clearance and family removal programs before closure of the dam. Studies made by the hydraulic engineers indicated, however, that construction of the river channel by cofferdams would create a hazard to life and property if discharges of considerable size occurred during the construction period. It was estimated that a

flow with an average frequency of once in 9 years would reach elevations ranging up to 910 between April 15, 1942, and completion of the project. Also, a flow of 40-year frequency would flood to elevations varying from 915 (prior to November 1) to 940 (after November 1) within the same period. Thus, in the lower reaches it was necessary to provide for protection against damages for which the TVA would have otherwise been liable even after acquisition of fee title or flowage easements had been negotiated. The matter was handled by specifying that the right to flood should become effective on all land below elevation 910 on April 15, that removal of all habitable buildings below elevation 915 by April 15 should be required, and that removal of all such buildings located between elevations 915 and 940 by November 1, 1942, should be required. Although it was realized that damage to crops above elevation 910 during the summer was a slight possibility, the additional cost of securing early possession to a higher level was not considered justified—a conclusion borne out by actual conditions of flow occurring previous to the final date of possession. Special forms of purchase contract were prepared by the TVA to cover the early flooding contingencies. Approvals issued specified which tracts required the special forms, set out the acreage involved (below elevation 910), and identified buildings to be removed by April 15 and/or November 1. A total of 139 tracts was involved, and early possession or flooding rights on nearly 2,200 acres of land was secured. Arrangements were made for the marking of the elevation 910 contour with blue-colored stakes as an aid in making appraisals and negotiating with the property owners. Also, the contour was shown on the land maps and the affected buildings were indicated.

The major individual holdings within the reservoir area were the lands owned by large canning corporations. A total of 15 percent of the acreage approved for fee or flowage easement acquisition was owned or controlled by these companies and their affiliates. Most of this land was used for growing vegetables for local canneries and averaged in value well above agricultural holdings of comparable size encountered previously in the valley. These vegetable lands were confined to the river bottoms which contrasted sharply with the thin soil of the adjoining ridges. In the lower reaches the bottom lands were completely covered by the lake, but in the upstream region only portions of the bottoms were inundated, and every effort was made in this section to leave in production all land not required for operation of the reservoir.

After the decision was made to protect the town of Dandridge, Tenn., by construction of a dike, detail studies were begun in order to establish the limits of acquisitions required for the levee, pumping station, storm water storage basin, two diversion dams, and diversion conduits. The sites for the dike, the pumping station, and the diversion dams were approved for fee purchase; permanent easements were approved for the storage basin (flowage) and two diversion conduits. In addition, it was necessary to secure temporary easements over strips of land adjacent to the conduit rights-of-way for storage, spoil banks, and other construction purposes, and also for a temporary access road to a borrow pit used in connection with the levee construction. During the time that plans were being developed for the backwater protection project, the Dandridge Planning Commission, with the assistance of

the state planning commission and interested visisions of the TVA, was studying the question of water-front adjustment. Upon final selection of the dike location, a definite plan was agreed upon and the land was approved for purchase.

A condensed summary of acquisition approvals for lands, easements, and other rights required for the Douglas project is given in table 36.

TABLE 36.—*Summary for acquisition approvals for lands, easements, and other rights required for the Douglas project*

Type of acquisition	Tracts	Acres
Fee simple:		
Dam site and access railroad	41	1, 209. 44
Reservoir and special uses	364	8, 860. 991
Total fee simple	405	10, 070. 431
Flowage easements	618	23, 093. 77
Miscellaneous:		
Permanent easements	48	89. 90
Temporary easements and permits	37	----------
Railroad right of way:		
Permanent easements	5	4. 45
[illegible]sements	7	----------
[illegible]		
Permanent easements	250	441. 98
Temporary construction rights	20	----------
Total approvals	1,390	33, 700. 531

Less than one-fourth of all the land purchased in fee lies above the surcharged pool level, and the majority of this was either required for the dam-site reservation or located on islands. Other lands were acquired for the access railroad, the nine saddle dikes constructed along the divide between the Valleys of Flat Creek and Millican Creek, the public access areas, the relocation of tracks and pumping facilities of the Southern Railway Co., the backwater protection works at the town of Dandridge, the malaria-control bases, and a few farm remnants.

LAND ACQUISITION

A total of 33,583.78 acres of land and rights in land was acquired for the Douglas project (table 37). Of this acreage 93.1 percent was purchased by voluntary transfer, 4.0 percent was condemned in order to obtain good title, and 2.9 percent was condemned because of refusal to sell at the appraised price.

Prices to be paid for land were fixed by TVA's appraisal staff. No price trading was permitted to enter into the negotiations, and the property could not be purchased for more or less than the figure set by the appraisal staff. In determining price ranges for various types of land all possible available information affecting land values was considered, including previous sales, local opinions of value, prices for crops and produce, rental terms, crop yields, and soil types. Price schedules were established for the various land classifications and other items of value comprising the properties to be acquired in order that equable prices be fixed. TVA sought to acquire the land at prices which would enable the owners to relocate and reestablish themselves in a manner that would afford them satisfaction equal to that which they were then enjoying.

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Concurrently with the appraisal work, abstracts of title were made and examined, curative field work was performed, and contracts were prepared for execution. Negotiations were then conducted with each owner for the conveyance of his property. After execution of a contract, all defects in title were cleared, payment made, and the deed for the property recorded. The transaction was usually closed within 30 days after execution of the contract.

Possession of about 2,000 acres lying below the 910 contour was required April 15, 1942, and it was necessary to make allowance in the appraisals for the value of growing crops on this acreage. On the remaining reservoir property, however, landowners were permitted to retain possession until December 1, 1942, which was shortly before inundation and after the harvest season, thus avoiding liability on the part of TVA for crop damages. The owners were also permitted to remove buildings and other improvements not needed by TVA, since the appraisal considered salvage value.

TVA's acquisition policy for this project required the purchase of the fee interest in the dam-site area, the right-of-way for the access railroad, tracts located entirely below pool level, and some lands required for special use. Unlimited flowage rights were acquired on the remaining properties below the 1,007 contour which was 5 feet above the elevation of the top of the spillway gates. Very few mineral deposits were found in the area. Table 37 gives a summary of land purchases as of June 30, 1946.

TABLE 37.—*Summary of land purchases for the Douglas project as of June 30, 1946*

Distribution of land purchases	Tracts	Acres	Total land and improvement cost	Average cost per acre
Fee (Reservoir and Railroad)	403	10, 057. 23	$1, 837, 542. 07	$182. 71
Flowage easement	614	23, 072. 27	4, 534, 095. 54	196. 52
Highway easement	253	454. 28	51, 001. 65	112. 27
Total or average[1]	1, 270	33, 583. 78	6, 422, 639. 26	191. 24

1. Not included is the cost of 72 miscellaneous rights, such as restricted use agreements, telephone line easements, and pipe line easements, amounting to $20,367.07 and charged to the land account.

The average cost per acre of $191.24 is the highest of any TVA reservoir acquired up to the time of the completion of the Douglas project. The principal factors contributing to this high cost were: (1) The location of the reservoir in an area especially adapted to large scale intensive vegetable production, (2) the unusually high proportion of reservoir land suitable for and devoted to such vegetable production, (3) the large number of substantial improvements of the better types and quality in the reservoir area, (4) the severe severance situation necessitating inclusion in the awards of large amounts for severance damages to unpurchased remainders and (5) a sharply rising farm real estate market.

The area had been particularly developed for intensive vegetable production as a result of the proximity of a number of canning plants; the two largest operators of such plants were Stokely Brothers & Co. and Bush Brothers & Co. These concerns, in addition to owning and operating large areas of land for supplying their canneries, leased

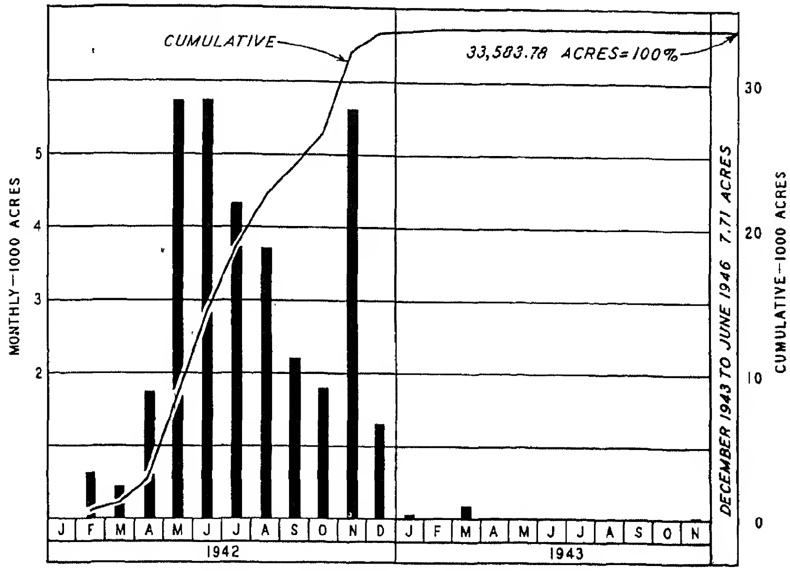


FIGURE 131.—*Summary of land purchases.*

other substantial areas for the same purpose and encouraged the farmers in the area to grow specified vegetables under contract for delivery to the canneries. The specialized farming involved in the intensive growing of vegetables required constant soil improvement by liming, fertilizing, soil building crops, tile drainage, and in some instances the installation of overhead pipe irrigation systems. Two to three crops of different vegetables were produced in succession during the growing season.

Of the total acreage acquired, 84 percent was cleared agricultural land, and of this cleared agricultural land 53 percent was comprised of river bottoms, creek bottoms, and terraces. A substantial proportion of the soil on these bottom and terrace lands was sandy silt loam, an excellent vegetable growing soil. The value of the cleared bottom and terrace lands ranged as high as $350 per acre; 5.8 percent was valued at over $300 per acre, 40.7 percent ranged in value from $210 to $300 per acre, 49.5 percent from $100 to $200, and only 4.0 percent was valued at less than $100 per acre. The average per-acre cost of the cleared bottom and terrace lands was $201.40; their total cost represents 45 percent of the grand total cost of the reservoir. Bordering the broad bottom lands were steeply rolling hill lands or knobs of considerably lower fertility and value than the bottoms; only a small proportion of such lands was included in the purchase area.

The total cost of the improvements, which averaged $38.08 per acre, represents 20 percent of the grand total reservoir cost. Most of the farmhouses were of substantial modern construction, barns were large and soundly constructed, there were a large number of concrete silos, and fields were well fenced. Part of the cost of improvements was

for rural community residences, stores, filling stations, schools, churches, and grain mills.

Severance damages to the unpurchased remainders of reservoir properties averaged $30.62 per acquired acre, or 16 percent of the total cost of these properties. The severance line included practically no overpurchase above the reservoir high water level. The remainders not purchased were left in irregular shapes and in many instances cut into several parts by projections of the reservoir; access to most of the remainders was impaired or totally destroyed; and there was very little land suitable for growing crops on the remainders, with the result that the majority could not be used for efficient farming operations. All these factors contributed to the high cost of severance damages.

According to the Farm Real Estate Index, farm real estate in Tennessee advanced in value approximately 9 percent from March 1, 1941, to March 1, 1942, and values continued to rise throughout the acquisition program. It was necessary to give consideration to this sharply rising real estate market in determining the cost of the properties acquired.

The reservoir area was easily accessible over a network of paved federal and state highways and improved county roads. It had adequate rail, motor freight, and bus service to large urban markets, within a convenient distance of the area, where supplies were obtainable. Good schools and churches were advantageously located throughout the area; and telephone, electric, mail, and rolling store services were generally available.

Expense of land acquisition, including appraising, buying, abstracting, title examination, closing, and the general administrative and clerical work amounted to $298,160.39 at June 30, 1946.

LOCAL GOVERNMENT FINANCE

The land purchased by the TVA for the Douglas Reservoir was formerly assessed for tax purposes at a total valuation of $1,567,070. This amount represented 5.9 percent of the aggregate tax base [3] of the four counties affected. On the basis of the average of tax levies for the last 2 years the property was in private ownership, this removal of real estate from the tax rolls reduced annual county revenues from ad valorem taxes by the total amount of $40,433. This was only 3.0 percent, however, of total annual revenues [4] from all sources in the four counties, since the property tax supplied only about one-half of the counties' total income. Receipts from the state in the form of grants and shared taxes provide most of the counties' revenues other than those from local property tax levies, and the former were little affected by the TVA's land purchases. Except for a number of tracts

[3] The base for measuring this reduction in the assessed valuation of taxable property in each county is the total assessment for the last tax year prior to the date when removal of property from the tax rolls began as a result of TVA purchase of land for the Cherokee or Douglas projects. Thus, the base year is 1940 for Hamblen and Jefferson Counties (which were affected also by the Cherokee project), 1941 for Cocke, and 1942 for Sevier. The former assessed valuation of TVA-purchased land is the assessment for the last year the land was actually subject to tax.

[4] Total revenues for the fiscal year ending August 31, 1941, for Cocke, Hamblen, and Jefferson Counties, and 1942 revenue data for Sevier County are taken as the base for computing this percentage and those in the last column of the tabulation, p. 281. These years are the last for which data are available before the revenue effects of TVA dam construction became noticeable in the respective counties.

in the town of Dandridge, all the land purchased by the TVA was rural and assessed for taxation on an acreage basis. The assessment of personal property and public utility properties was not materially affected. Detailed data on tax losses, by counties, are shown in the following tabulation.

County	Former assessed valuation of TVA-purchased land		County tax levy on TVA-purchased land	
	Amount	Percent of total county assessment	Amount	Percent of total county revenues
Cocke	$376,390	5.2	$9,483	2.5
Hamblen	54,160	.7	1,167	.4
Jefferson	1,061,760	14.3	26,226	7.2
Sevier	74,760	2.0	2,557	.7
Total or average	1,567,070	5.9	40,433	3.0

The annual property tax levy of the State of Tennessee on TVA-acquired land was $1,250; and the total assessment of land acquired inside Dandridge was only $12,000, resulting in an annual reduction of city property taxes of about $150, or 6 percent of total revenues.

TVA payments in lieu of taxes

Under the provisions of section 13 of the TVA Act, as amended by the Norris-Sparkman bill in June 1940, the TVA makes payments in lieu of taxes to the states and counties in which it owns and operates power property, including dams and reservoirs. The total payment in any year is based upon a percentage of the TVA's gross revenues from the sale of power during the preceding year, the rate gradually dropping downward from 10 percent for the fiscal year ending June 30, 1941, to 5 percent for the fiscal year 1949 and each year thereafter. One-half of the percentage payment is distributed among the several states in proportion to the book value of TVA power property located within the respective states, and one-half is distributed in proportion to the revenue from the sale of electric power by the TVA in the respective states. A minimum guaranteed payment is provided for each state equal in amount to the 2-year average of state and local property taxes formerly levied on power property purchased by the TVA and on that portion of reservoir lands allocated to power purposes. A direct payment is made to counties equal to the county and district portion of the former property tax as defined above; the amount thus paid to counties within each state is deducted from the payment otherwise due the respective state governments.

With respect to all the main-river dams and the first two tributary storage projects completed and added to the TVA multiple-purpose system, the TVA allocated 40 percent of the cost of reservoir lands to power purposes. Construction of the Douglas project, however, was authorized by Congress as a part of an emergency program to provide additional power urgently required due to the war emergency. The Douglas project is a multipurpose project which was operated for power purposes as long as that method of operation was required to meet war power commitments. While so operated, its entire cost was charged to power. Near the end of the war, as the period of

critical war power demand ended, the cost of the emergency projects was reallocated in accord with the normal multiple-use principles governing TVA dam operations.

As a consequence of the cost-allocation policies discussed above, the TVA replaced—up to June 30, 1945—the entire amount of county property taxes lost because of acquisition of land for the Douglas project. Beginning with fiscal year 1946, however, the county payments were adjusted to the basis of 40 percent tax replacement in accord with the permanent allocation of reservoir land cost to power purposes on the books of the TVA.[5]

RESERVOIR CLEARING

Reservoir clearing activities on the Douglas project were started February 2, 1942, and were rushed to completion by February 19, 1943, when closure of the dam was made. Operations were carried on under a high-pressure schedule on a 6-day 48-hour workweek. Despite rationing, manpower problems, and other wartime limitations, the job was done in an entirely satisfactory manner. The terrain which had to be cleared was principally semimountainous and in a predominantly agricultural section. The timber to be cleared consisted of the various species of mountain timber, most of the merchantable quantity of which had been cut and removed from the area constituting the reservoir proper. Some merchantable timber located in the more remote and inaccessible areas still remained. Along the stream banks there was generally a fringe of large overhanging timber, principally of species with little or no commercial value. The actual wooded areas cleared and prepared for flooding amounted to 5,182 acres.

The task of producing large quantities of cofferdam logs and lumber for dam-construction needs was launched immediately upon authorization of the project and kept pace successfully with dam construction. Operations produced 5,800,000 board feet of lumber sawed and delivered to the dam and 47,118 logs delivered for cofferdam construction. The most of this timber was purchased from land surrounding and outside of the reservoir proper.

The field office at Morristown, Tenn., from which the Cherokee clearing activities were conducted, was suitably situated geographically for the Douglas work and therefore this office was retained. A superintendent was placed in charge, who reported directly to the division superintendent in the administrative office, Chattanooga, Tenn. Assigned to the superintendent was a staff of assistants who directed the various phases of field work on the project, and a chief clerk directed the accounting, timekeeping, warehousing, and the general business affairs relating to the project.

Foremen and supervisors turned in daily to the office time reports for men working under their supervision. The workmen also were spot-checked on the job by a timechecker to assure proper time reporting and payment for time worked by the workmen. Reconciliation was made between the supervisor's time report and the time checker's spot-check report and discrepancies were adjusted. The time

[5] Each of the counties affected by the Douglas Reservoir also receives payments in replacement of all the county taxes formerly levied on power property purchased therein by the TVA from private utility companies.

checkers also delivered payroll checks to workmen on the job on pay days. Pay day was every 2 weeks. Time checkers were furnished pick-up trucks for travel between the office and the reservoir area in which they transported tools and field supplies needed by various crews of workmen.

Financial statements and cost analyses were prepared monthly. Cost and progress reports were prepared daily. Such other reports as force, attendance, etc., were prepared daily and as required. Needs for materials and supplies were anticipated, and requisitions for purchase were initiated as required.

In close proximity to the project office were field offices maintained by other divisions of the TVA engaged on the Douglas project. A close coordination was maintained between the superintendent and the representatives of these contacting divisions on the project.

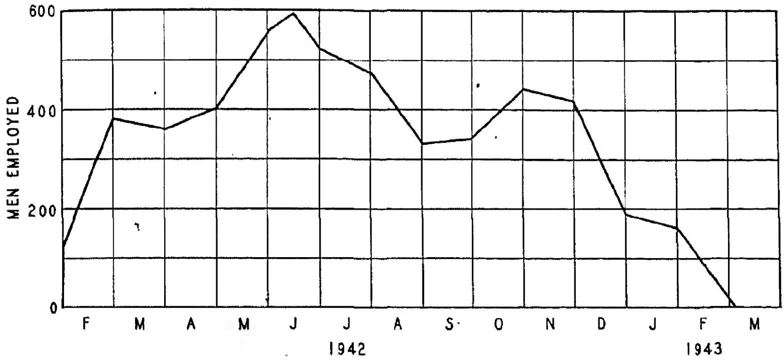


FIGURE 132.—*Reservoir clearance personnel.*

Because of the emergency nature of the Douglas project, there was no opportunity to purchase land or obtain right of entry thereon prior to the start of construction. Because of this situation, practically all the lands in the reservoir area were entered upon for clearance purposes simply by obtaining permission from the landowners. The people of the reservoir area were friendly and cooperative, and little difficulty was encountered in securing permission to clear and remove timber from the lands.

In the selection of workmen for reservoir clearance work, farm labor was used to the greatest possible extent because that type of labor is more familiar with the use of edged tools and the hazards of timber and woods work. White labor altogether was employed on this project since there was an insufficient amount of Negro labor in the area from which a clearance unit could be recruited. The peak of employment on the project was 593 and was reached in May 1942. Because of the urgency of completion of the project at the earliest possible time a 6-day 48-hour workweek schedule was put into effect from the start.

The greatest precautions were taken to avoid accidents on the job. In spite of the hazardous nature of clearance work, lost-time accidents were kept at a minimum. Of a total of 921,071 man-hours worked, there were 14 chargeable injuries and 657 man-days lost. There were

no fatal injuries. The accident frequency rate for the clearance project was 15.2,[6] and the severity rate was 0.60.[7]

Types of clearing

Complete clearing was carried out between elevations 1002 and 930. Within this draw-down area clearing was classified as regular clearing and totaled 4,044 acres. Below elevation 930, standing timber which extended above elevation 930 was felled and wired in place and was classified as wiring down. There were 354.6 acres of wiring down. Timber cleared along 81 stream-bank miles, involving 783.4 acres, was classified as bank clearing.

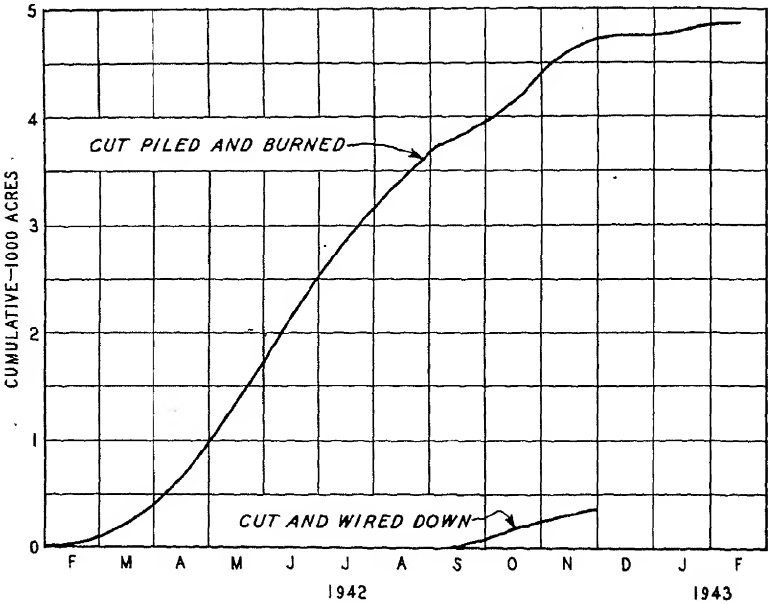


FIGURE 133.—*Reservoir acres cleared.*

A unit foreman was in charge of each clearing unit. A regular clearance unit was comprised of 3 labor foremen, 1 saw filer, 1 ax filer, 1 clerical first aid laborer, 1 timberjack, 50 to 60 laborers, and snaking teams as required.

Regular clearing is that other than along stream banks or where mechanical equipment is not required. A regular clearing unit was subdivided into three components, namely, a bush hook and ax crew, a saw crew, and a piling crew, each under the supervision of a labor foreman. The bush hook and ax crew cut and piled the underbrush and small timber; the saw crew felled the larger timber. In felling the large timber, all merchantable logs were cut into stock lengths and left for removal and production into lumber. The piling crew with mule teams piled all the remaining timber and debris, leaving the area

[6] Chargeable injuries per million man-hours worked.
[7] Days lost per thousand man hours worked.

ready for burning, with the exception of merchantable timber which may have been left for removal and production into lumber.

Wiring down is more economical than complete clearing, and after impoundage the area is permanently inundated, out of sight, and of no further interference. For anchorage, No. 8 annealed steel wire was used. This wire was securely wrapped and stapled in as many places as deemed necessary, never less than two places about the tree being wired down, and then tightly and securely wrapped and stapled around an adjacent standing tree, stump, or other securely anchored objects.

Bank clearing is the classification covering the clearing of timber from stream banks where mechanical equipment is required for withdrawing timber from the streams. For pulling the timber from streams, crawler-type tractors with side winch, boom, and stiff-leg were used generally; however, smaller type tractors, 25 horsepower caterpillar with rear-mounted towing winch were used to some extent, especially in the pulling of the smaller and lighter timber. These tractors worked in conjunction with the clearance crews.

FIGURE 134.—*Steep shore line clearing along the right bank of the French Broad River.*

A bank-clearing unit was comprised of 4 labor foremen, 1 tractor operator, 1 saw filer, 2 timber riggers, 1 timberjack, 1 ax filer, 1 clerical first aid laborer, 60 to 70 laborers, a tractor, and mule teams as required. A bank-clearing unit was subdivided into four components, each under the supervision of a labor foreman. First, a crew cut and piled the underbrush and small timber and felled the timber to be pulled by the tractor. The tractor and its ground crew then followed, pulling the trees from the stream. Next, a crew with axes and saws felled and trimmed the large and remaining standing timber. Following behind this group, the piling crew with mule teams did the piling of the logs and debris for burning.

The type of clearing generally referred to on main-stream reservoirs as marginal clearing was not done on the Douglas project.

Complete clearing was done to elevation 1002, 2 feet above normal maximum pool level. On steep shore line exposed to the main body of the reservoir, or of a soil likely to be eroded by wave action, complete removal of all timber and brush was carried out for a horizontal distance of approximately 6 to 12 feet or more, depending on the degree of wave action expected, beyond the 1002 contour. No clearing in flat areas or bights above elevation 1002 for the stranding of drift or flotage was deemed necessary, nor was done because of the clearing of the two additional feet above the normal maximum pool level.

Low stumping of timber cleared in the flat areas between elevations 992 and 1000 was carried out, where practical, at time of clearing to facilitate future mowing of annual growth as an aid to the control of mosquito breeding. Stumps in these areas were cut approximately 4 inches above ground, except that no effort was made to cut large trees lower than in normal clearance practice.

Burning of debris

The burning of timber and debris was accomplished by both contract and force account. Where done by contract, it was through the letting in small parcels and, generally, to residents within the reservoir area. Generally, those taking such contracts were local farmers. This policy resulted in the giving of employment to many who could spare some time from their farms and to others who were ineligible for employment with the TVA because of old age, physically unfit, or without the experience required by the TVA for clearance work. The availability of sufficient contractors within the reservoir area proved to be inadequate, and burning by force account had to be resorted to in a considerable measure. There were 223 contracts executed for burning debris under which 3,791.5 acres was burned. There was 1,035.9 acres burned by force account.

Reshrubbing

A clean shore line and water surface for malaria control was prepared for fluctuation stages between elevations 992 and 1002. It was not possible to prepare a clean shore line for effective malaria control below elevation 992. This reshrubbing work was done over the entire shore line of the reservoir and required the cutting and disposal of all sprouts and annual growth over an area of approximately 3,435 acres. In areas which were not adaptable for use of mowing machines and hay rakes, this phase of the work was done by labor crews using such tools as sythaxes (weed cutters) and bush hooks. This phase of the work was begun early in September 1942 to avoid regrowth along the margins before impoundage.

Drainage of isolated pools

In shallow areas near the 1002 contour there were a number of depressions which would not drain after impoundage during the drawdown period. Specifications required that these depressions be connected to the main body of the reservoir through the construction of canals. The construction of these projects was confined to the zone between elevations 992 and 1002. The larger of these projects was constructed by ½-cubic-yard draglines. Some of the smaller projects were done by hand by men with shovels or by teams and hand scrapes. There were eight such projects constructed, involving the excavation of 15,549 cubic yards of earth. Construction of canals of this nature

FIGURE 135.—*Saw crew felling large timber.*

FIGURE 136.—*Cofferdam logs being loaded in reservoir area for delivery to Douglas Dam.*

made it possible for depressions to drain, or partially drain, or fill with the fluctuation of the lake. They also provided boat channels for larvicidal work, thus facilitating the future control of malaria.

Miscellaneous clearing activities

Crop and fence damage claims.—The assistant superintendent in charge of burning operations also was assigned to the appraising and settling of crop and fence damage claims resulting from clearance operations. Clearance operations were carried on almost entirely under authority of permits from the landowners; as a general policy, owners were allowed to remain in possession and farm their lands through November 30, 1942. Therefore, in order to maintain a schedule it was found expedient to destroy and pay for a portion of the growing crops rather than delay operations, or to employ the use of

more expensive clearing methods. Efforts were made, however, to avoid the destruction of crops as much as possible. There were 242 claims of such character investigated and settlement recommended. Claims not exceeding $50, where all parties were in agreement, were paid on the job. Claims in disagreement, or those in excess of $50, were forwarded to the TVA's legal staff for handling.

Timber utilization.—The time required for completion of the dam was dependent upon the rapidity and regularity with which logs and lumber could be delivered. By April 9, 1942, the 47,118 logs required for cofferdams were delivered at the dam site. The production of 5,800,000 board feet of lumber was a continuous operation until February 1943. Surveys of timber on lands within the reservoir area proper were made promptly, but this source could only supply a small percentage of the requirements. While timber crews began the cutting and handling of this timber, negotiations were started with owners for the purchase of timber from lands in the surrounding vicinity of the reservoir. At the same time, invitations to bid were being issued on the sawing and delivery of lumber and the furnishing of trucks for hauling cofferdam logs. Several tracts of timber were found available, purchased, and a contract was made for the sawing, delivery of lumber, and the hauling of cofferdam logs. As a means of expediting production, logs for both the manufacture of lumber and for cofferdam use were cut by the TVA's forces. Continued search for and optioning of timber was carried on until adequate quantities had been located.

Because of the need for all the timber developed through clearance operations of the reservoir in the construction program, there was no merchantable timber available for sale to private purchasers. Waste timber, for firewood, was made available to local farmers and those who would remove it from the area as it was being cut.

Demolition of buildings and structures.—The general surrender date of lands in the reservoir was December 1, 1942. The closure of the dam was scheduled for February 19, 1943. This allowed a period of

FIGURE 137.—*Cofferdam logs yarded at Douglas Dam.*

2½ months for the covering of the entire reservoir in the clean-up and disposal of buildings, fences, farm bridges, and other obstructions. As of December 1, the surrender of possession date, much of the crops, personal property, and improvements had not been removed by the owners, but convincing efforts and interest in doing so were displayed and, through cooperation with them, this was accomplished without detriment to the schedule.

Naturally, there were some owners who were unwilling to sell their property at the price offered, and as a consequence the property had to be acquired through condemnation. In such instances the buildings, fences, and improvements became the property of the TVA. These were advertised and sold through competitive bidding. There were six contracts made for the sale of buildings and improvements acquired on condemned lands.

TABLE 38.—*Douglas Reservoir clearance operations*

Item	*Unit*	*Total*
Normal maximum pool elevation	foot	1, 000
Pool-clearing elevation	do	1, 002
Length of shore line at elevation 1002 feet	mile	556
Length of reservoir at elevation 1002 feet	do	43. 0
Pool area at elevation 1002 feet	acre	31, 300
Total land area purchased	do	33, 200
Wooded areas cleared between elevations 930 and 1002	do	4, 827. 4
Wooded areas wired down below elevation 930	do	354. 6
Total areas cleared and wired	do	5, 182. 0
Regular clearing	acre	4, 044. 0
Bank clearing	do	783. 4
Total complete clearing	do	4, 827. 4
Man-day average per acre	man-day	14. 4
Cutting and wiring down	acre	354. 6
Man-day average per acre	man-day	9. 0
Total clearing and wiring	acre	5, 182. 0
Total man-day average per acre	man-day	14. 0
Burning	acre	4, 827. 4
Reshrubbing	do	3, 435. 5
Boat harbors prepared	do	23. 5
Drainage of isolated pools	cubic yard	15, 549. 0
Channel markers installed—posts	post	32
Disposal of buildings and fences	dollar	34, 285. 47
Timber utilization:		
Lumber manufactured by contract for construction	fbm	5, 860, 552
Cofferdam logs produced for construction	each	47, 118
Damage claims investigated		242

NAVIGATION PREPARATION

Preliminary investigations

In 1940 TVA made studies of the major navigable tributaries of the Tennessee River for the purpose of determining whether future improvements on these tributaries should include provisions for navigation facilities. Analysis of traffic potentialities of the French Broad River indicated that development of both the French Broad and Holston Rivers for navigation probably will never be feasible since they serve virtually the same territory. The studies further indicated that while canalization of the Holston River might some day be economically justified, this probably will not be true of the French Broad River. For these reasons no provision was made at Douglas Dam for the future installation of navigation locks.

Navigation on the completed reservoir will be confined to recreational boating and the operation of small craft for malaria control, land management, and similar uses with possible occasional local movements of forest products or other materials. Under these circumstances the extensive program of safety harbor construction, channel grading and cut-offs, channel marking, flush cutting of stumps, and similar work normally performed in the Tennessee River main channel reservoirs was not undertaken in Douglas. The reservoir preparation program was confined to the bare essentials required for the safety of small craft and included the following activities: (1) rebuilding bridge and wire crossings to meet authorized clearance standards; (2) cutting stumps flush with the ground surface or stumping certain critical areas; (3) demolishing and removing certain navigation obstructions and hazards such as bridge piers, silos, and foundation walls; (4) establishing a skeleton system of navigation daymarks, direction boards, and other aids; (5) preparing navigation maps.

Bridge and wire crossings

The United States Corps of Engineers concurred in the use of secondary reservoir channel clearances for all wire and bridge crossings over the reservoir (see table 39), with the exception that the minimum horizontal clearance was increased to 100 feet. These

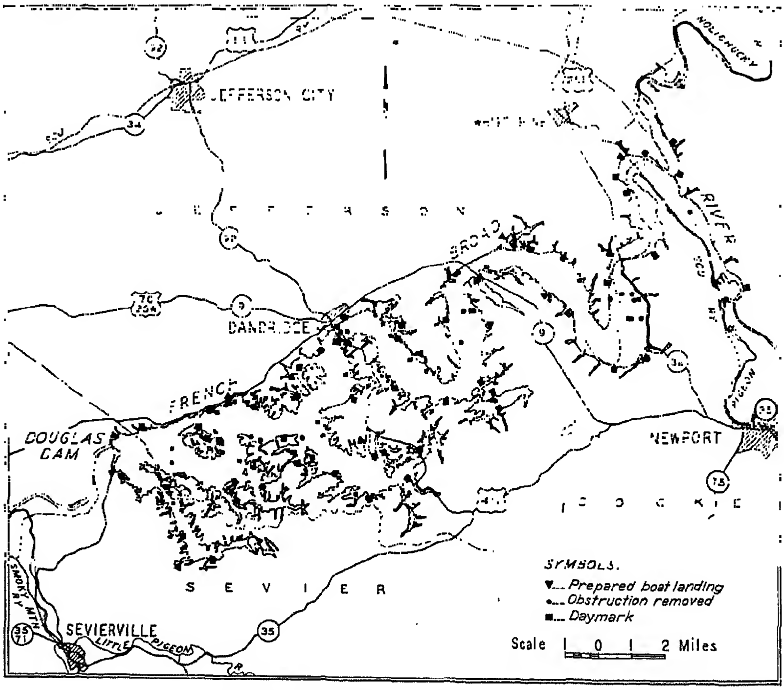


FIGURE 138.—*Reservoir preparation for navigation.*

clearances provide adequately for malaria control craft and all pleasure boats except sailboats. Since there are no bridges in the lower part of the reservoir, which is best adapted to sailboating, the clearances should not greatly restrict the use of this type of craft.

There are five bridges across the main stream within the limits of the reservoir: the Dandridge Highway Bridge at mile 45.1, the Swann Highway Bridge at mile 54.3, the Walters Highway Bridge at mile 64.2, the Southern Railway bridge at mile 67.8, and the Rankin Highway Bridge at mile 71.3. These crossings were in existence before reservoir construction was begun, and because of the low elevation of the original structures they were either raised in place or rebuilt at relocated sites. In addition to these main stream crossings, a county highway bridge was erected by the Hamblen County Bridge Committee within the limits of the reservoir on the Nolichucky River at mile 5.3.

The five bridges crossing the French Broad River have an underclearance elevation of 1017 or more, and a channel-span horizontal clearance of at least 100 feet. The Hamblen County Bridge over the Nolichucky River has an underclearance elevation of 1015.

The two transmission lines and one railway signal control line which crossed the reservoir were reconstructed to conform with the standard clearances prescribed for secondary reservoir channels.

TABLE 39.—*Recommended navigation clearances*

Structure	Clearances (feet)											
	Main stream			Major navigable tributaries			Secondary reservoir channels			Shallow draft navigable waters		
	Horizontal	Above normal pool	Above maximum flood of record	Horizontal	Above normal pool	Above maximum flood of record	Horizontal	Above normal pool	Above maximum flood of record	Horizontal	Above normal pool	Above maximum flood of record
Bridges	350	57	40	200	42	25	50	15	------	8	6	------
volts	------	77	60	------	62	45	------	35	20	------	25	------
More than 132,000 volts	------	82	65	------	67	50	------	40	25	------	30	------
Telephone and telegraph lines and stream-gaging and ferry cables	------	67	50	------	52	35	------	25	10	------	15	------

Stumping

Stumps were not removed along the channels or principal sailing courses because: (*a*) the cost would be excessive in view of the large draw-down in this reservoir, (*b*) the benefits would be limited because of the character and extent of navigation expected to develop in the future, and (*c*) stumps alternately submerged and exposed may be expected to disintegrate within a relatively few years anyway.

Stumping was confined to 17 areas along the reservoir's edge. These areas are well distributed throughout the length of the reservoir and were selected as the most likely points where small boats would be regularly moored or would be launched from automobile trailers (see

fig. 138). To insure safe landing conditions in these selected areas and to minimize the possibility of damage to moored boats during periods of receding water levels, all stumps at the landing sites were removed or cut flush with the surface of the ground.

Preparation of these landings and harbors was confined to the removal of stumps and other obstructions below the normal pool elevation. No docking facilities or shore structures were constructed. The basic underwater work, however, was completed so that hazards would not exist at a later date if full development of the harbors under local initiative is realized.

In addition to these seventeen landing and harbor areas, stumps were removed along the back side of Morris Island (mile 72), and the channel was marked with posts and tree trunks to facilitate navigation by boats performing malaria-control work.

Removal of navigation hazards

Field inspection of the reservoir area disclosed a large number of structures such as silos, bridge piers, and concrete foundations, some of which would be serious hazards to navigation after the reservoir had filled. The following rules were adopted as general guides for determining whether a specific structure should be demolished: (1) structures that might cause loss of life were removed; (2) most structures located in areas where intensive navigation was expected were removed; (3) structures projecting above elevation 1002 were not removed unless their foundations were insecure; (4) most structures below elevation 940 were not removed because of the short duration of reservoir stages lower than 940 elevation, and because those stages normally occur during a season unsuitable for extensive boating.

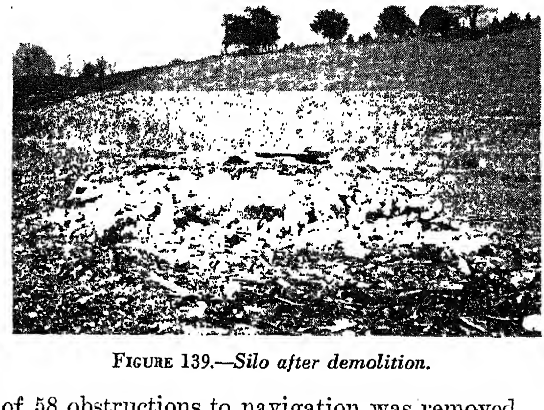


FIGURE 139.—*Silo after demolition.*

A total of 58 obstructions to navigation was removed. This number was composed of 14 silos, 30 concrete or brick foundations and pillars, 5 concrete water troughs, 4 small concrete and brick houses, 2 sets of bridge piers, 1 concrete flume, 1 concrete dam, and 1 concrete well curb. Locations of hazards which were removed or destroyed are shown in figure 138.

A new and highly satisfactory method was developed for destroying concrete silos. Holes were dug in the ground at 10-foot intervals

around approximately two-thirds the inside circumference of the silo. A total of 100 pounds of 40-percent dynamite was placed in these holes. When this charge was detonated the resulting blast threw the silo over on its side in the direction of the unloaded segment. The fall crushed the silo, leaving a flat pile of debris with very few jagged edges (see fig. 139.)

Navigation markers

The type of navigation which operates on a lake like Douglas does not normally require a continuous marked channel from one end of the lake to the other; neither is there justification or need for providing lighted aids for night navigation. On the other hand, unless identifying markers of some type are provided, small-boat operators are unable to readily find their way around the reservoir and frequently get lost. In the Douglas Reservoir this problem was handled by installing three types of navigation aids: daymarks and direc-

FIGURE 140.—*Daymark for Douglas Reservoir.*

tion boards on shore, and poles in the water to mark particularly hazardous submerged knolls which were quite distant from the shore line.

Forty-eight daymarks were placed at strategic locations along the shore line (see fig. 140). These markers, 4 feet high by 6 feet long, have large black numerals painted on a white background. Locations of the markers with their corresponding numbers were shown on navigation maps of the reservoir, thus enabling navigators to use the maps to establish their exact position on the lake.

The daymarks were constructed of $\frac{3}{16}$-inch tempered Prestwood framed with 1- by 3-inch hardwood strips. They were suspended on hammock hooks to reduce wind load on the supports which consisted of cedar pole frames set in concrete or in some cases the daymarks were attached to trees. The black numerals were made 35 inches high and are legible at a distance of about one-half mile. Under average conditions the daymarks are visible for a distance of about 2 miles.

Fourteen direction boards were placed at major channel intersections and other strategic locations. These boards are similar to highway direction signs and indicate the direction and waterway distances to major landings and towns.

During the summer months when boating will be at a maximum, Douglas Lake will usually be at or near elevation 1000, which is its normal maximum elevation. At this stage there are a large number of knolls that may be more than a half mile from the shore line but are only a few inches or a few feet below the water surface. The most critical of these knolls, those above elevation 980, were marked by cedar poles placed on their crests and set 3 or 4 feet deep in concrete. The tops of the poles project about 3 feet above full pool elevation, and the top 3 feet was painted white.

Navigation maps

For the information of navigators and others, a complete set of navigation maps was prepared to a scale of 1 inch equals one-half mile. Three sheets, each 17 by 22 inches, were needed to cover the reservoir. The maps were prepared in four colors with the depths of water being indicated in various shades of blue. The locations and numbers of all navigation daymarks were shown. Certain areas considered especially hazardous to the operation of boats were indicated by a red overprint. In addition to showing the lake itself, the maps also show drainage, roads, buildings, wooded areas, and other features of the region surrounding the reservoir. The preparation of these maps is explained in more detail on page 269. Prints may be obtained at a small cost from the Tennessee Valley Authority's central map and drawing files in Knoxville and Chattanooga, Tenn., or from principal boat dock operators throughout the reservoir.

POPULATION READJUSTMENT

Reservoir families

Upstream from the Douglas Dam site the French Broad River makes abrupt, deep bends which form broad and fertile bottom lands. A half dozen creeks empty into the river from the south, the small valleys of which lay parallel to the river. Five hundred and twenty-five families lived in these bottom lands and valleys which now form Douglas Lake. Their removal was required in the unprecedented short period of 10 months from the date the dam was started.

Twenty of these families were located on the dam site and construction area and were required to move at once. It was also necessary to move 14 families and 1 school for the construction of 8 saddle dams between the hills south of the dam. Nine families and one service station moved from Dandridge when a protective dike was built in that village.

At the same time the evacuation of the dam site was taking place, a survey was being made of the reservoir area by the Tennessee Agricultural Extension Service. The information obtained from families during this survey, together with information secured from other sources, formed the basis of a study and appraisal of evacuation and readjustment problems.

The economy of the reservoir area was primarily agricultural. On the creek lands were communities of small farmers, and the broad river bottoms were owned by large operators. On the large holdings, the production of corn, livestock, and specialized vegetables and

fruits for commercial canning prevailed. The average family cash income for all families in the reservoir area was $1,115 in 1941, as reported by the families.

The population was 62 percent tenants, a large number of whom were day laborers. There were only 10 Negro families in the area. Seventy-three percent of families displaced were farming at the time the dam was started; however, the majority of the residents had farmed at some time in their lives. Half of the families had lived at their former homes in the reservoir for over 5 years, but only 18 families had lived at the same location for life.

One hundred and fifty-five families used electricity before moving. This is a fairly high proportion when it is realized that the population was predominated by tenants. Most of the families used wells or springs for their water supply, and only 18 residents reported a pressure system or city water supply.

The families of the area were divided into tenure groups as follows:

Tenure:	*Number*	*Percent*
Farm owners	156	29.7
Farm tenants	229	43.6
Nonfarm owners	45	8.6
Nonfarm tenants	95	18.1
All families	525	100.0

In addition to the families, the following institutions and business establishments were displaced by the flooding of Douglas Reservoir:

Institution or business:	*Number*
Schools	10
Churches	13
Mills (saw, flour, and feed mills)	16
Post offices	1
Stores	16
Garages	1
Restaurant	1
Cannery	1
Warehouses	2
Total	61

Resources available for readjustment

The shortness of the construction period and the enormous amount of work to be accomplished made all divisions of the TVA more dependent upon each other. Each operation of the entire construction program had to be completed on schedule in order that the dam could be finished by the scheduled date. Evacuation of families was sandwiched between the acquisition of reservoir land and the clearance of the reservoir. Notification of the acquisition of tracts of land was transmitted daily from the Land Acquisition Division, and the Reservoir Clearance Division was kept informed of areas in which families and buildings had been removed. Similar coordination of activities with other divisions greatly facilitated the evacuation program.

Residents of the area who were not needed on the farm in connection with the harvesting of crops or removal of buildings were able to obtain employment with TVA. This was an aid to TVA, which was attempting to recruit labor very rapidly, and to families, some of whom were greatly in need of additional resources with which to move.

As in the evacuation of other TVA reservoir areas, assistance in locating new homes, farms, or business establishments was available from established agencies for those who needed and desired assistance. Most important of these organizations was the Tennessee Agricultural Extension Service, which, through a contract agreement with TVA, secured information with respect to farms available for rent and for purchase and made this information available to those directly affected by the purchase of land for Douglas Reservoir. Other local agencies, such as county welfare departments and health units, gave the advice or assistance each was equipped to give where it was needed. Civic organizations were helpful in the solution of community problems as were town and county officials.

Removal and readjustment of families

The denseness of the population, the large number of buildings to be moved, and the harvesting of crops constituted the principal evacuation problems. The number and size of buildings per farm unit were large, and almost all the land was tillable. The crop season of 1942 was the most favorable in years. The Nation was at war and the farmers had been urged to increase production. There was no further incentive to conserve the land which would be flooded, therefore, pasture, hay land, and waste land had all been planted resulting in a crop that would have taxed harvesting facilities in normal times. In addition to harvesting and removing these crops, the people had to find new homes and remove their buildings, fences, stock, and equipment by December 1. Less and less labor was available and under a growing and changing set of governmental restrictions upon the use of trucks and building materials their problems became increasingly difficult. These operations were further handicapped by snow and cold weather during the early winter.

As tracts of land were purchased by TVA, owners and occupants were urged to make their relocation plans at once so that they could determine what problems might arise in connection with removal. Many buildings were removed intact, but there was only a limited number of moving contractors available in the vicinity. It was necessary to obtain priority assistance for those desiring to rebuild, and sometimes delays occurred in the procedure established with the War Production Board. Some residents who were too busy to move their buildings bought homes elsewhere and sold their improvements. Fortunately, migration took place gradually and in different communities at different times so that it was possible to direct the flow of movers and building and wrecking contractors from community to community as needed.

The easement contract, under which most of the land was purchased for the Douglas Reservoir, allowed owners to retain the use of the land subject to flooding and other rights of TVA so that farmers could make a limited and specialized use of the land.

The shore line of the lake is reasonably regular in the areas where the adjacent upland is fertile, but very irregular in regions where the upland is sterile and unproductive. The readjustment of communities near fertile areas took place with reasonable speed and a minimum of problems, but in the other areas more assistance was necessary to effect a satisfactory adjustment. Additional adjustments will take place gradually with the assistance of the county agents and local

associations of the farmers themselves. Other agencies will also continue their active interest in the families known to them. Because of the proximity of the Smoky Mountains and large industrial centers, recreation has furnished new opportunities.

Most of the families relocated in the counties in which they formerly lived. Only 11 families moved to other states. The following tabulation indicates the net loss or gain of families in each county:

County	Number families moved	Number families relocated	Net loss or gain
Jefferson	387	252	−135
Sevier	73	104	+31
Cocke	64	75	+11
Hamblen	1	8	+7
Total	525	439	−86

PLANNING ASSISTANCE TO THE TOWN OF DANDRIDGE

Before Douglas Dam had been authorized by Congress and while its construction was still in the discussion state, representatives of the town of Dandridge requested an opportunity to discuss with TVA the need for the dam and the effects which its construction would have upon the town. A delegation of officials and citizens of the community met with representatives of TVA in September 1941, when all facts and circumstances of the proposed project were reviewed, as well as physical and economic readjustments and problems facing the town if the reservoir was to be constructed. Even though a considerable sentiment against the project existed at that time in Dandridge and its trade area, this meeting served to establish a cordial working relationship between the people of the community and the TVA.

Immediately after congressional authorization of Douglas Dam, Dandridge established an official planning commission to deal with readjustment problems and requested assistance from the Tennessee State Planning Commission and the TVA. The town planning commission first asked TVA to determine the feasibility of constructing a dike to protect the center of the town, which included the Jefferson County Courthouse, Shepard's Inn, and other historic buildings, as well as many of the business establishments and some residences. Engineering studies indicated that it would be feasible to construct a dike about 900 feet in length and 50 feet in height to protect most of the town center. These studies and the overwhelming sentiment of the community in favor of such a dike led to TVA's decision to construct it. The decision was announced at a meeting of the planning commission in March 1942 and was greeted by expressions of appreciation on the part of the town for the joint working out of this method of preserving the community center.

At the meeting, Chairman Lilienthal made it clear that the capable way in which the planning commission had presented to the TVA the disruptive effects of the reservoir upon the town had a great deal to do with the conclusion to build the dike. With this major planning decision made, it was possible for the planning commission, with the assistance of the Tennessee State Planning Commission and TVA, to study the many other problems of physical readjustment. Alternate

sites for relocation of the bridge spanning the French Broad River at Dandridge were studied, and it was found possible to select the site desired by the community. The town planning commission also studied various proposals and adopted a plan for developing the areas adjacent to the dike and the bridge abutment for future recreational use.

In acquiring land for the dike, the TVA purchased a 100-year-old residence, which it used temporarily for some of its own offices. The planning commission has developed plans for preserving and using this building as a community center. Arrangements are now under way for lease by the town of this fine old building, and of other water-front property acquired by the TVA, for recreational purposes. Preliminary plans have also been developed for a regional park and boat harbor on the lake front across the new bridge from Dandridge. The planning commission is preparing to be of service in recommending tourist facility development and zoning and land-use controls to guide the extensive postwar growth which the outstanding lake scenery and central position of the town seem to warrant.

BACKWATER PROTECTION

Communities affected by the reservoir were the town of Dandridge and the villages of Rankin, Oak Grove, and Shady Grove. A levee was constructed to protect the business section of Dandridge, and at Rankin, affected properties were acquired in fee; a strip immediately above the pool contour was needed for the Southern Railway relocation. Most of the Oak Grove and Shady Grove settlements were below the normal reservoir level, and consequently were approved for fee acquisition; however, protection was provided for most of the French Broad Baptist Church property (at Oak Grove) by filling around the building and installing a small pumping plant for the disposal of storm water and sewage during high reservoir stages.

Town of Dandridge

The town of Dandridge, county seat of Jefferson County, is situated on hillsides on the right bank of the French Broad River about 8 miles upstream from Douglas Dam. A gully with steep banks opened toward the river before construction of the Douglas project. Two creeks, North Creek and West Creek with a combined drainage area of about 525 acres, flowed together in the lower part of the town and discharged through the gully into the French Broad River.

At maximum reservoir level, elevation 1002, a large section of the town would have been flooded, including the courthouse and other buildings of historical and sentimental value. The feasibility of protecting Dandridge from the reservoir backwater was therefore investigated, and general plans for protection of the town were submitted and approved. A protective earth dike was constructed across the gully. The drainage area behind the dike was subdivided into two parts.

The area above maximum pool level is drained by gravity flow into the reservoir. For this purpose, small diversion dams were built across North Creek and West Creek, and large pipe culverts carry the collected surface water by gravity from these dams to the reservoir. Additional surface water is collected from side valleys below the diver-

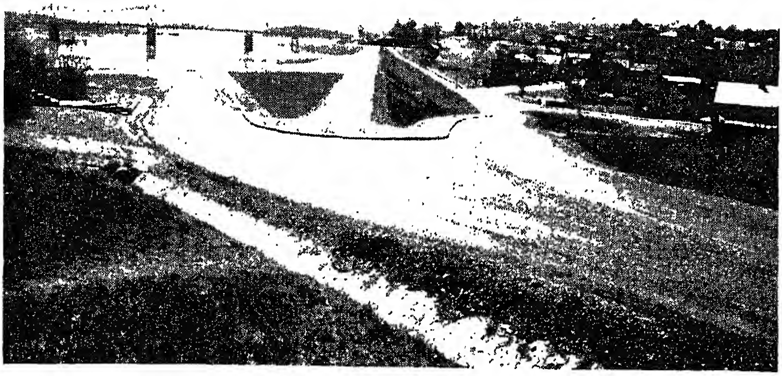


FIGURE 141.—*Dandridge dike.*

sion dams and carried by smaller pipes to the main culverts. Street drains are also connected to the culverts where possible.

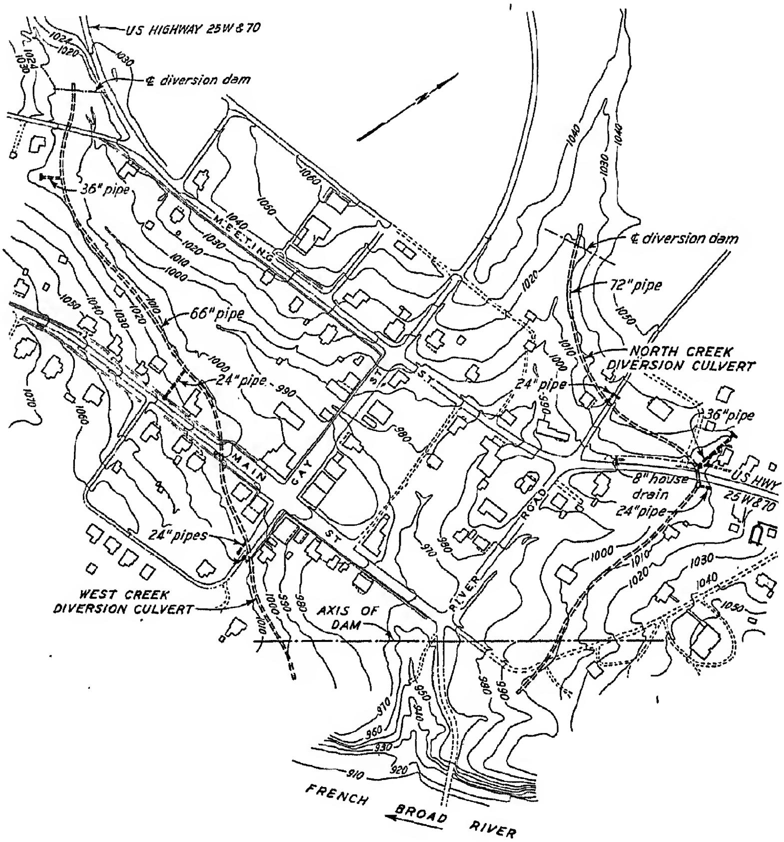
The drainage from the area below maximum pool level and the town sanitary sewerage are collected at the toe of the dike. A culvert under the dike discharges this run-off to the reservoir. At low reservoir stages, this discharge is by gravity; at high stages, pumping is required. A general plan of the protective works is shown in figure 142.

Main embankment.—The foundation at the dike consists of Knox dolomite formation. The rock was exposed in the creek bed and in the steeper parts of the gully, but was covered on the banks by an overburden of clay varying in depth to a maximum of about 25 feet. The rock formation was full of seams, pinnacles, and cavities, which required extensive treatment to provide a satisfactory base for the earth structure and an elaborate grouting program to secure a safe and tight foundation.

Satisfactory material for an earth-fill structure was located on the riverbank a short distance downstream from the site; and the cross section of the dike was designed for uniformly impervious rolled-fill material with the saturation line controlled by internal drainage.

The embankment is about 1,000 feet long, with a 16-foot-wide crest at elevation 1013, or 11 feet above maximum headwater level. To avoid extending the upstream toe along the steep creek bed into the French Broad River and to protect the toe from discharges from the North Creek culvert, a stabilizing rock-fill toe was constructed across the creek bed. A 6-foot-thick filter section was placed between the impervious fill and the rock fill. The entire upstream embankment slope above the rock-fill toe was covered with 1.5-foot-thick hand-trimmed riprap on a 9-inch layer of gravel. The downstream slope was furnished with a 66-foot-wide berm at elevation 982 for the relocation of streets to this level and to allow access to the pumping station

and room for the substation. A 9-foot-wide berm was constructed along the downstream slope on the south bank for a walkway to the south abutment, and a 30-foot-wide berm was provided along the downstream slope on the north side for construction of a road and walkway between the pumping station and the north abutment of the dike.



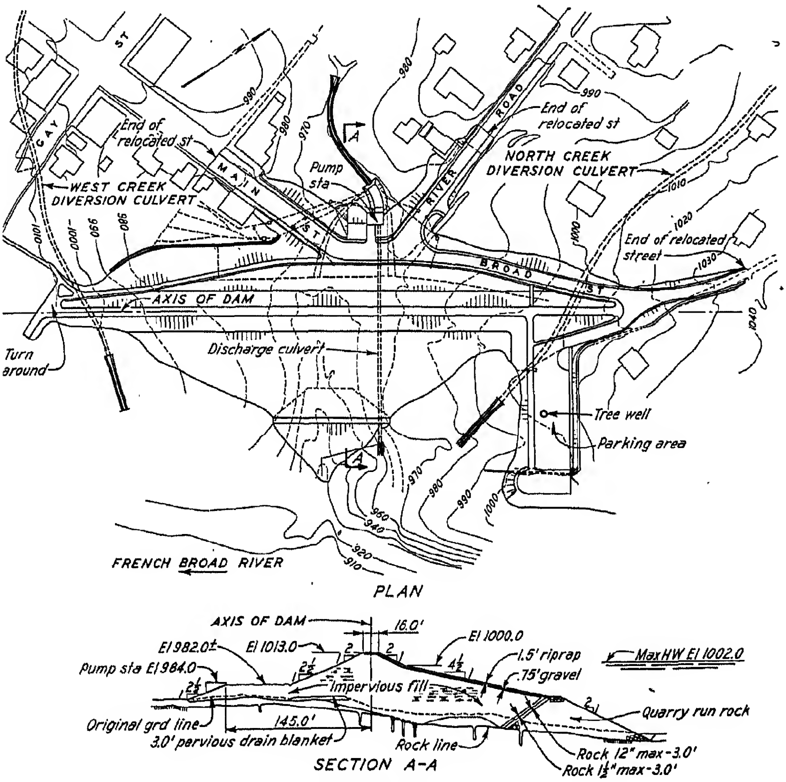
(a) *Plan of town of Dandridge.*

FIGURE 142.—*Backwater*

The design of the section of the dike was based on the following assumptions: From tests in the soils laboratory, a value of 26° for angle of internal friction of the earth fill was adopted. Cohesion of the material below the saturation line was neglected, and above the saturation line the cohesion was taken as 200 pounds per square foot. Angle of internal friction of drain blanket, rock fill, riprap, and gravel was taken at 45°. With these basic assumptions, the Swedish slip-circle method was used for design. The upstream slope was

designed for sudden draw-down from maximum headwater elevation 1002, and the downstream slope was designed for an operating condition with headwater at elevation 1002, with downstream toe saturated to elevation 965 and a saturation line in the embankment at the maximum level that could be established by this condition. For these design conditions, a factor of safety of 1.3 was obtained for the upstream slope and of 2.0 for the downstream slope.

The entire downstream slope was seeded. A drainage system, discharging into the pump basin, was installed along the road and



(*b*) *Dike plan and section.*

adjustment at Dandridge, Tenn.

walkway berms and at the downstream toe of the dike. A system of French drains discharging into a manhole with a measuring weir for intercepting and measuring the seepage through the foundation was installed in the flat hollow between the toe and the relocated Main Street.

A public overlook with parking area has been provided on the reservoir bank at the north abutment of the dike. The parking area, which will accommodate about 35 cars, is gravel-surfaced and edged

by log curbs. Gravel-surfaced walkways lead from the overlook along both sides of the parking area to the north end of the structure. The top of the dike has a 12-foot-wide gravel-surfaced walkway, which also serves as patrol road; and gravel-surfaced walkways extend from the north and south ends of the dike along the downstream slope to the road intersection at the pumping station. For plan, sections, and details of the dike see figure 142.

Diversion dams and culverts.—The diversion dams at the North Creek and at the West Creek are impervious rolled-fill dams with 6-foot-wide crest and side slopes of 1 on 3. The upstream slopes are protected by 1-foot riprap on a 6-inch layer of gravel, and the downstream slopes are seeded. The dams are provided with 15-foot-wide reinforced concrete side channel spillways, with the crests 4 feet below the top of the dam. These spillways will discharge run-off in excess of the culvert capacities back into the old creek beds, which lead to the pumping station. Top elevations of the North Creek and the West Creek diversion dams are 1034 and 1024, respectively. The lengths of the two dams are approximately 210 and 170 feet, and their maximum heights are about 22 and 14 feet.

Discharge capacity of the diversion culverts was based on a 2-inch run-off per hour with water levels behind the diversion dams at elevations 1030 and 1020, or 4 feet below the top of the dams, and with reservoir level at elevation 1002. Both culverts are provided with reinforced concrete intakes with steel trashracks, and wire rope trash fences were placed across the creek beds about 100 feet upstream from the intakes. A steel grate was embedded in the headwall at each outlet to prevent entry into the culverts.

The culverts consist of precast tongue-and-groved reinforced concrete pipes laid with cemented joints. The culvert outlets have reinforced concrete-lined channel extensions to protect the reservoir banks and the main embankment from erosion at the outlets.

Pumping station.—A combined sanitary sewage and storm water pumping station was constructed at the toe of the embankment near the intersection of the relocated Main Street, River Road, and Broad Street (see fig. 142). The building is a two-story reinforced concrete structure and is founded on rock in the old creek bed. The station contains an ejector pit, with floor at elevation 959 and a control room at elevation 973.5, for the sewage system and a drainage sump and pressure chamber for the storm water system. A stairway over the pressure chamber provides access to the control room from the pump deck at elevation 984.

Intercepting sewers were constructed to carry the sewage to the pumping station. When the reservoir level is above elevation 962, the sanitary sewage flows to two motor-driven pneumatic sewage ejectors. These ejectors are rated at 100 gallons per minute each against 45-foot total dynamic head. The ejectors discharge into an 8-inch cast-iron pipe line extending through the embankment and connecting to an existing sewer which formerly discharged into the French Broad River. Provision was made for bypassing the sewage ejectors when the reservoir is below elevation 962. There is also provided a connection from the ejector inlet line to the storm water pump suction well to bypass a portion of the sanitary sewage if the flow should

exceed the capacity of the sewage ejectors. The ejector compartment of the station contains a 2,000-cubic-foot-per-minute fan for ventilation, two 6-kilowatt electric heaters for heating, and a small sump pump for drainage.

Open drainage ditches were constructed to carry storm water to the pumping station. Three motor-driven pumps are installed in the pumping station. Two of these pumps are rated at 6,000 gallons per minute each against 33-foot total dynamic head, and the third pump is rated at 1,240 gallons per minute against 37-foot total dynamic head. The pumps discharge into a pressure chamber from which a 36-inch square culvert extends through the dike and enters the reservoir at approximately invert elevation 960. The pumps are automatically controlled by float switches. A 30-inch bypass pipe was installed between the suction well of the pumps and the pressure chamber to permit gravity flow of storm water when the reservoir is below elevation 963.75. This bypass has a sluice gate at the inlet end and a flap valve at the discharge end. A 16-inch connection to the pressure chamber takes the discharge from a portable pump in cases of emergency.

Waterworks adjustments.—Approximately 1,200 feet of 6-inch water main was installed on Broad Street, Main Street, and River Road. Three fire hydrants were relocated and three sectionalizing valves were installed. The existing mains under the new embankment and access roads were abandoned. Approximately 600 feet of 2-inch main on Gay Street was replaced with 2-inch wrought-iron pipe. The new 6-inch mains are class 150, cast iron, bell and plain end.

French Broad Baptist Church (Oak Grove Community)

The French Broad Baptist Church is located on the right bank of the French Broad River at approximately river mile 54. In order to avoid moving this church and all the graves in the adjacent cemetery, an earth levee with a top elevation of 1,005 was constructed to protect the church and churchyard from inundation by the reservoir.

A storm water pumping station was constructed at the church to discharge drainage over the levee.

HIGHWAY AND RAILROAD RELOCATION

The Douglas project involved the construction of 4.07 miles of access roads (including 1.78 miles of roads to saddle dams), 5.34 miles of state highways, 35.22 miles of county highways, 0.39 mile of streets in Dandridge, and 12.48 miles of tertiary roads. In addition the TVA surfaced 18.23 miles of access roads to provide adequate access to the dam site. Also, 2.90 miles of county highways and 1.14 miles of streets in Dandridge were resurfaced because the original surface was damaged or destroyed by the large amount of excessively heavy traffic and the heavy equipment used by the TVA in the various construction operations.

The railroad work involved in connection with the Douglas project consisted of the construction of a temporary access railroad to the dam site and the permanent relocation of portions of Southern Railway lines in the vicinity of Leadvale, Tenn.

HIGHWAYS

Contracts were made with the State of Tennessee, the counties of Sevier, Jefferson, Hamblen, and Cocke, and with the town of Dandridge, for adjustment of highways and streets submerged or otherwise affected by the reservoir. This adjustment consisted of relocating or raising the roads and streets which were in or adjacent to the reservoir. The contracts provide for the abandonment of certain roads and streets which were rendered unnecessary by such adjustment, or by the TVA's purchase of land for the reservoir. They also stipulate the general locations, roadbed widths, minimum elevations, and other relevant design data, and release the TVA from all liability in connection with the inundated highways and streets. Compensation was made to Hamblen and Cocke Counties in lieu of reconstructing the approaches to Solomon Ferry.

It was necessary for the TVA to make replacements of existing facilities, using equivalent standards of design. When improved standards beyond equal replacement were desired, the governmental agency making the request participated in the cost of construction to the extent of the improvement, and under this arrangement the state agreed to construct the permanent pavement on 4.13 miles of the above state highways.

On completion of the highway and street construction, the roads, bridges, streets, and other appurtenances, together with their rights-of-way, were conveyed to the respective governing agencies, who thereupon released the TVA from further liability in connection with their use and maintenance.

A summary of the access, state, and county highways, and city streets affected and reconstructed in the reservoir area is given in the following tabulation:

	Miles
Reconstructed by TVA:	
Access roads	4.07
Access roads improved and surfaced	18.23
State highways	5.34
County highways:	
Principal county highways	35.22
County highways resurfaced	2.90
Tertiary roads	12.48
City streets	.39
City streets resurfaced	1.14
Total for project	79.77

Access highways

Access to the dam site was provided by the construction of a road from the Shady Grove-Dandridge Road to the north end of the dam and a road from the River Road south of the French Broad River to the construction plant below the dam. These roads were constructed 31 feet wide between shoulders and surfaced with a bituminous top 22 feet wide on a stabilized stone base 6 inches thick.

Access roads were also constructed to the saddle dams. These roads, in general, were constructed 18 feet wide with a traffic-bound surface course applied at the rate of 600 cubic yards per mile. One, immediately adjacent to the dam area, was constructed 28 feet wide with a compacted surface 6 inches thick and 20 feet wide.

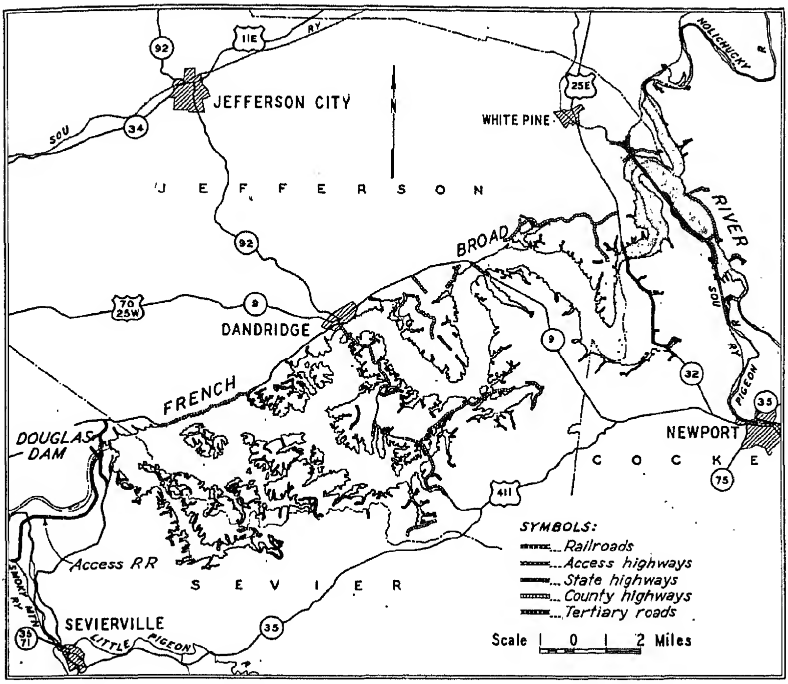


FIGURE 143.—*Highway and railroad relocation.*

To facilitate access to the dam area, the county road to United States Highway No. 70, the one leading to Dandridge, and the one connecting the south access road to Sevierville were surfaced with a light carpet treatment of bituminous material. On the road to Sevierville a new bridge 77 feet long was constructed over Millican Branch, and the timber deck of the bridge over Little Pigeon River at Sevierville was rebuilt and strengthened.

Portions of the access roads, later connected by project 3081, were conveyed to Sevier County, Tenn., in compliance with the contract with that county.

A summary of the access roads constructed and surfaced is given in the following tabulation:

	Miles
Access roads to dam	2.29
Access roads to saddle dams	1.78
County roads surfaced (light bituminous treatment)	18.23
Total	22.30

State highways

It was necessary to replace a section of United States Highway No. 25E (Tennessee State Highway No. 32). The TVA was obligated only to the extent of replacing this highway to the same standards of width, alinement, gradients, and surfacing as existed; however, the

state desired to have this road constructed to higher standards and paid for the increase in cost caused by the higher standards. In addition, it was necessary to raise the Swann Bridge across the French Broad River on United States Highway No. 70 (Tennessee State Highway No. 9) and several hundred feet of roadway on each side of this bridge above the effect of the reservoir. There was no improvement in type and consequently no state participation was involved in this section.

The reconstructed highways were built to a minimum elevation of 1,007 feet above mean sea level, with a width of 42 feet between shoulders. Cut slopes in earth are not steeper than 1 : 1 and fill slopes outside of the reservoir are 1½ : 1 or flatter. All fills that are exposed to the action of the lake are 1½ : 1, or flatter, and are protected against wave action by a blanket of rock of such dimensions as deemed necessary for each case. The minimum width of right-of-way is 120 feet.

TABLE 40.—*Summary of bridge construction*

Project and location	County or carrier	Type	Number spans	Length (feet)	New	Reconstructed	Raised
Access highways:							
Little Pigeon River	Sevier	Steel, timber, and masonry.	2	243		x	
Millican Creek	do	Timber and concrete.	4	77	x		
State highway system:							
Swann Bridge—Reservoir.	Jefferson	Steel and concrete.	39	2,561			x
Walters Bridge—Reservoir.	Jefferson and Cocke.	do	24	1,765			x
County highway system:							
Douglas Dam Bridge.	Sevier	Steel, timber, and concrete.	7	873		x	
Dandridge — Reservoir.	Jefferson	Steel and concrete.	8	1,508	x		
Clear Creek	do	Concrete	1	80	x		
Muddy Creek	do	Steel and concrete.	3	216	x		
Indian Creek	do	do	5	507	x		
Long Creek	Hamblen	Timber and concrete.	5	135	x		
Clay Creek	Cocke	Concrete	1	108	x		
Rankin	do	Steel, timber, and concrete.	13	919			x
Railroad:							
Leadvale	Southern Ry.	Steel, concrete, open deck.	7	803	x		
U-pass	do	Steel, concrete, ballast deck.	3	79	x		

Major bridge construction was the Swann Bridge on United States Highway No. 70 and the Walters Bridge on United States Highway No. 25E. Both bridges are across the French Broad River. The original Swann Bridge, 1,868 feet long, consisted of 1 main truss span 280 feet, 4 truss spans totaling 426 feet, 2 steel-girder spans totaling 142 feet, and 20 concrete-deck viaduct spans totaling 1,020 feet. The existing bridge was raised vertically a height varying from approximately 32 feet at the west end to 41 feet at the east end. On the west end a 33-foot viaduct span was removed and three new viaduct spans totaling 128 feet were added. On the east end 10 new viaduct spans totaling 528 feet were added. The total out-to-out length of the new bridge including 70 feet of abutment spans is 2,561 feet.

The original Walters Bridge, 1,709 feet long, consisted of three main truss spans totaling 596 feet and 21 concrete-deck viaduct spans totaling 1,113 feet. The existing bridge and viaduct spans were raised vertically 10 feet. Abutment wings was the only new construction. The out-to-out length of the raised bridge including abutment spans is 1,765 feet.

FIGURE 144.—*Walters Bridge on United States Highway No. 25E.*

These bridges were raised with no betterment in the type, width, or load-bearing capacity.

Minor drainage consisted of nine reinforced concrete box culverts, varying in size from 4 by 3 feet to 12 by 14 feet, and reinforced concrete pipe culverts with concrete end walls.

County and tertiary roads

Contracts were made with the various counties covering the adjustments necessary to maintain a system of roads which would fulfill the functions of the existing system. Due consideration was given to the fact that certain lands would be flooded or otherwise taken out of private use. The new roads, where affected by the reservoir, were constructed to a minimum elevation of 1,007 and to widths varying from 22 to 31 feet depending on the new traffic conditions or on the width of the existing road. Cut slopes in earth are not steeper than 1:1 and fill slopes above the reservoir not steeper than 1½:1. Where fill slopes are exposed to wave action they were generally constructed 1½:1 or 2:1 and in addition were protected by a blanket of rock of such thickness as was required in each case.

Because of variations in the existing roads and the varied effect of the reservoir, there is no one standard of width, side slopes, or wave protection. Right-of-way is 50 feet in width, generally.

Tertiary roads affording access to established roads from dwellings, industries, farm lands, and other improved property isolated by the reservoir were constructed where, in the judgment of the TVA, such construction would cost less than the purchase of property involved. These roads were constructed to standards of width, alinement, and grade lower than those used for the county roads, and the right-of-way provided is 30 feet wide.

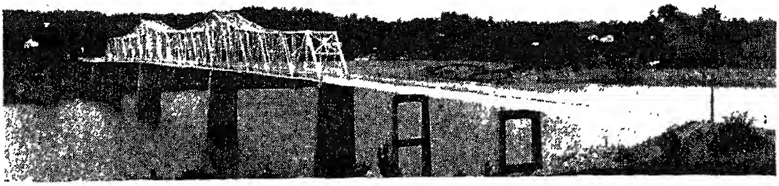


FIGURE 145.—*Dandridge Bridge across the French Broad River.*

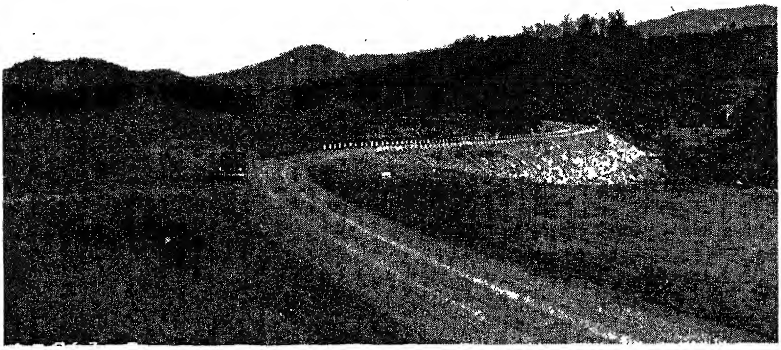


FIGURE 146.—*County road at Anderson Branch.*

A new bridge, 1,508 feet long, was constructed across the French Broad River at Dandridge. The superstructure of the old bridge at Dandridge was purchased by Sevier County and erected by the TVA across the river below the dam. The bridge at Rankin was raised. Five other bridges, totaling 1,046 feet in length, were constructed on the county system of roads. Minor drainage was provided by pipes or reinforced-concrete box culverts. A total of 40 box culverts, varying in size from 6 by 4 feet to 12 by 20 feet, were constructed.

The roads constructed were located as follows:

County	County highways, miles	Tertiary roads, miles	Total miles
Sevier	2.16	1.00	3.16
Jefferson	31.06	7.85	38.91
Hamblen	.14	.19	.33
Cocke	4.76	3.44	8.20
Total	38.12	12.48	50.60

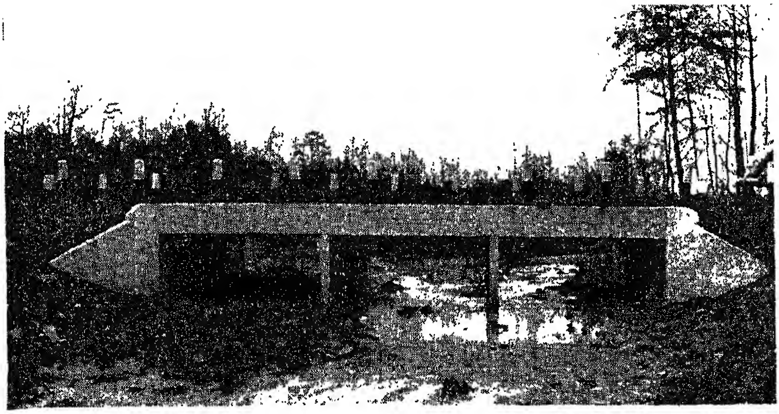


FIGURE 147.—*Seehorn Creek culvert.*

City streets

The contract made with the town of Dandridge for the construction of a dike, with contingent adjustments of water and sewer systems, also provides for the construction of several city streets.

Under this contract, 0.39 mile of streets was constructed. Portions of Gay, Hill, Main, and Broad Streets, and River Road were constructed, together with necessary curbs, gutters, sidewalks, and drainage systems.

RAILROADS

The temporary access railroad was constructed by the TVA from a connection with the Smoky Mountain Railroad at Ewing siding, which is located 4 miles north of Sevierville, Tenn., to the dam area, a distance of 5.6 miles where, together with the access road approaching the dam from the south, it crossed the French Broad River on a temporary timber trestle. In addition to the main spur, about 1.6 miles of receiving, storage, and service tracks were constructed in the dam and shop area. In order that delivery of construction materials would not be delayed because of the physical condition of the Smoky Mountain Railroad, the TVA entered into an agreement requiring the raiload company to rehabilitate its line between Knoxville and the point of connection of the access railroad at Ewing siding.

The Southern Railway is the only railroad having facilities affected by the Douglas Reservoir. Adjustments consisted of relocating the river line (Knoxville to Asheville division) between mile posts S210.1 and S217.4, also the Leadvale cut-off (Leadvale to Bulls Gap) from its connection with the river line immediately west of the French Broad River bridge to milepost B. L. 16.3, a distance of approximately 0.6 mile. In addition to the trackage and necessary appurtenances, other facilities replaced include a new 803-foot bridge across the French Broad River consisting of six deck-plate girder spans, and one through-plate girder span, each approximately 114 feet in length, all on a reinforced concrete substructure; a mechanical electrically

operated coal and sand handling plant; water supply facilities, including an electrically operated pumping plant on the Nolichucky River; and replacement of all signal and communication facilities. Minor drainage structures consist of five reinforced concrete box culverts varying in size from 3 by 4 feet to 12 by 20 feet, also a considerable number of pipe culverts of various sizes.

The relocated facilities are constructed to a minimum subgrade elevation of 1,006. Roadways generally are 20 feet wide in cuts and 20 feet plus one-tenth the height in fills. Cut slopes in earth are not steeper than 1:1. Fill slopes are 1½:1 above and 2:1 below elevation 1006. All fill slopes exposed to the reservoir are protected by rock fill revetment of a thickness deemed necessary in each case. Right-of-way is generally 200 feet wide.

FIGURE 148.—*Leadvale Bridge—Southern Railway (old bridge in foreground—before removal).*

Southern Railway watering station, Leadvale, Tenn.

The relocation of a section of the Southern Railway to clear the backwater from Douglas Dam necessitated the abandonment of the existing pumping station and water station.

A new pumping station, two water storage tanks (one of which was furnished by the railway), three water columns, and a water supply line were provided. The pumping station is located on the south bank of the Nolichucky River arm of the reservoir near the Hamblen-Jefferson County line. The storage tank and water column are located on the south side of the railroad paralleling the French Broad River arm of the reservoir. The new pump-room floor is at elevation 1015. The lower portion of this station serves as a pump suction well. This suction well is connected to the reservoir through two 10-inch cast-iron pipe lines, one at elevation 992.42 and one at elevation 974.42.

Two deep-well-type pumps are installed in the pumping station. These pumps are rated at 500 gallons per minute each at 100-foot total dynamic head. The pumps discharge through a 10-inch line approximately 7,500 feet long to the storage tank. The pipe and valve arrangement in the pumping station is such that the lower intake line can be flushed from the full intake well or from the storage tanks or

pumps. Because of heavy accumulations of sand and silt in the pump well, a sand eductor was installed in the pit with discharge through a 3-inch pipe out through the upper 10-inch intake pipe. A centrifugal pump, with suction connection to the main station discharge line, furnishes operating water to the eductor.

The river intake is provided with a screen to prevent the entrance of trash which would clog the eductor or pumps.

The wooden storage tanks are 30 feet in diameter by 20 feet high, and each has a capacity of 96,000 gallons.

Float switches are provided in the storage tank to start and stop the pumps in the pumping station.

A motor-driven centrifugal fan was provided for ventilating the pumping station.

UTILITY RELOCATION

The power, telephone, and telegraph lines below the pool level were removed during the period between February 1942 and May 1943.

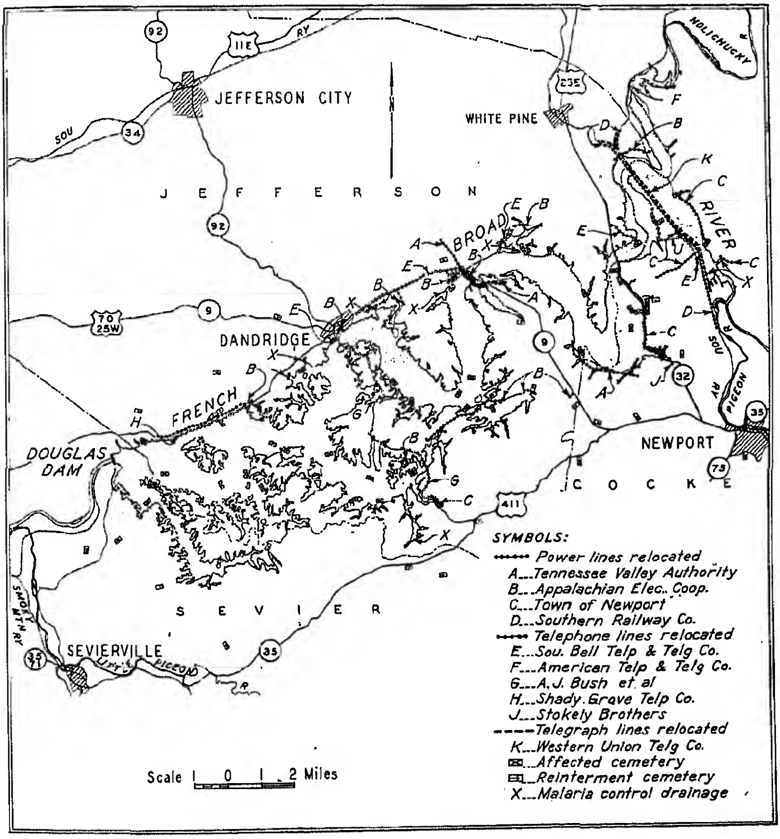


FIGURE 149.—*Utility and cemetery relocations.*

The major portion of the removal and relocation work was performed by the TVA under the terms of contracts negotiated with the utility owners. The remainder of the work was handled by the utility owners with their own forces in accordance with agreements previously executed by the TVA and the owners. Litigation was not necessary in any instance.

A total of 121.5 miles of utility lines was removed from the reservoir; 73.3 miles of new lines were constructed to replace the lines removed. In addition, 9.5 miles of lines were adjusted or relocated to avoid interference with construction work of the TVA.

The cost to the Douglas project for this work was about $150,322. Approximately $142,836 was expended for reservoir work; $7,485.40 was spent to clear for construction work of the TVA.

CEMETERY RELOCATION

Reconnaissance surveys to determine the locations of cemeteries which would be affected by backwater due to construction of Douglas Dam were made during the latter part of the summer of 1941. It was found that 44 cemeteries would either be totally or partially inundated when the reservoir was full or access to them would be impaired. However, several of these cemeteries were very old and had been abandoned for many years. The identity of all graves was unknown, and there was no request for any action to be taken. Due to lack of identification information after diligent effort, removal operations were performed in only 32 of the 44 affected cemeteries.

The actual work of investigating, surveying, and mapping these cemeteries and the procuring of agreements was started immediately after authorization of the Douglas project by Congress as a part of the war construction emergency program. This work was carried on until April 1942 and was followed by removal operations. From April until September 1942 the relocation of 2,449 graves was made, with the exception of 114 graves which were not relocated until December 1942 and January 1943 because of a delay in acquiring the title for one of the cemeteries. To comply with the wishes of the nearest of kin of the deceased, it was necessary to reinter graves in 95 different cemeteries. A total of 1,379 monuments, ranging in weight from a few pounds up to 7 tons, was moved and reset in the reinterment cemeteries. At the request of the nearest of kin, 104 graves in affected cemeteries were left undisturbed.

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Chapter 7

INITIAL OPERATIONS AND RELATED DEVELOPMENT ACTIVITIES

For the duration of the wartime emergency, regulation at Douglas Dam for flood-control and navigation benefits was subordinated to the production of power, although some benefits were derived. Among the activities connected with the reservoir operation are fish and game protection, forestry, land management, and recreational development, all of which were to a certain extent curtailed during the war years.

INITIAL POWER OPERATIONS

The Douglas powerhouse has two generating units each with a rated capacity of 33,333 kilovolt-amperes at 0.9 power factor, or 30,000 kilowatts. Test runs were started on the first of these generators March 16, 1943, and the machine was placed in commercial operation March 21, 1943. Tests were started on the second unit January 3, 1944, and the unit was released for commercial operation January 12, 1944. Provision has been made for the installation of two additional generators at this location.

The operation of the Douglas Reservoir is coordinated, in accordance with its original design as a multiple purpose project, to provide storage in advance of floods, to fluctuate the pool elevations as an aid to malaria control, and to store water during periods of small stream flow increases for later use for power generation.

The dam was closed and storage of the entire inflow of the French Broad River was begun February 19, 1943. The stream flow was used for storage and the generation of power until March 4, 1944, when it became necessary to open the gates to pass flood waters.

The gross generation of the Douglas Dam hydro plant during the first 51 months of operation was as follows:

Period of operation	Output, kilowatt-hours	Average output, kilowatts	Peak load, kilowatts
Mar. 16, 1943–June 30, 1943	70, 694, 000	27, 500	31, 000
July 1, 1943–June 30, 1944	309, 587, 000	35, 200	64, 000
July 1, 1944–June 30, 1945	364, 983, 000	41, 700	64, 000
July 1, 1945–June 30, 1946	315, 608, 000	36, 000	65, 000
July 1, 1946–June 30, 1947	287, 635, 000	32, 800	64, 000
July 1, 1947–April 30, 1948	188, 677, 000	25, 800	62, 000

Table 41 shows the energy generated at Douglas, by months, during the first 51 months of operation of both units.

TABLE 41.—*Initial power operation by months*

Month	Energy		Peak load kilowatts	Generator rated capacity kilowatts (2 units)
	Kilowatt-hours	Average kilowatts continuous		
1944				
February	10,933,000	15,700	61,000	60,000
March	35,486,000	47,700	64,000	60,000
April	29,978,000	41,600	64,000	60,000
May	43,719,000	58,800	64,000	60,000
June	46,011,000	63,900	64,000	60,000
July	38,483,000	51,700	64,000	60,000
August	30,866,000	41,500	64,000	60,000
September	23,264,000	32,300	60,000	60,000
October	22,395,000	30,100	50,000	60,000
November	27,647,000	38,400	50,000	60,000
December	27,569,000	37,100	44,000	60,000
1945				
January	29,995,000	40,300	42,000	60,000
February	26,203,000	39,000	56,000	60,000
March	41,341,000	55,600	59,000	60,000
April	37,721,000	52,400	56,000	60,000
May	18,539,000	24,900	64,000	60,000
June	40,960,000	56,900	64,000	60,000
July	36,937,000	49,600	64,000	60,000
August	32,494,000	43,700	54,000	60,000
September	26,169,000	36,300	50,000	60,000
October	28,495,000	38,300	46,000	60,000
November	14,557,000	20,200	32,000	60,000
December	18,014,000	24,200	41,000	60,000
1946				
January	23,746,000	31,900	48,000	60,000
February	20,391,000	30,300	40,000	60,000
March	28,742,000	38,600	50,000	60,000
April	35,501,000	49,300	61,000	60,000
May	17,522,000	23,600	60,000	60,000
June	33,040,000	45,900	65,000	60,000
July	43,077,000	57,900	64,000	60,000
August	38,644,000	51,900	64,000	60,000
September	24,474,000	34,000	52,000	60,000
October	21,989,000	29,600	40,000	60,000
November	14,171,000	19,700	27,000	60,000
December	6,975,000	9,400	15,000	60,000
1947				
January	22,588,000	30,400	58,000	60,000
February	17,435,000	25,900	44,000	60,000
March	28,239,000	38,000	48,000	60,000
April	31,443,000	43,700	50,000	60,000
May	24,871,000	33,400	48,000	60,000
June	13,729,000	19,100	39,000	60,000
July	11,514,000	15,500	44,000	60,000
August	13,797,000	18,500	48,000	60,000
September	19,176,000	26,600	43,000	60,000
October	19,052,000	25,600	40,000	60,000
November	27,424,000	38,100	42,000	60,000
December	16,544,000	22,200	37,000	60,000
1948				
January	2,226,000	29,900	10,000	60,000
February	20,198,000	29,000	49,000	60,000
March	28,582,000	38,400	50,000	60,000
April	30,164,000	41,900	62,000	60,000

The personnel required for the operation of the dam and powerhouse is shown in figure 150. The number of employees shown in this figure is based on a 40-hour workweek. Because of the nearness of the plant to the towns of Sevierville and Dandridge, Tenn., no new housing facilities were constructed for the operating personnel.

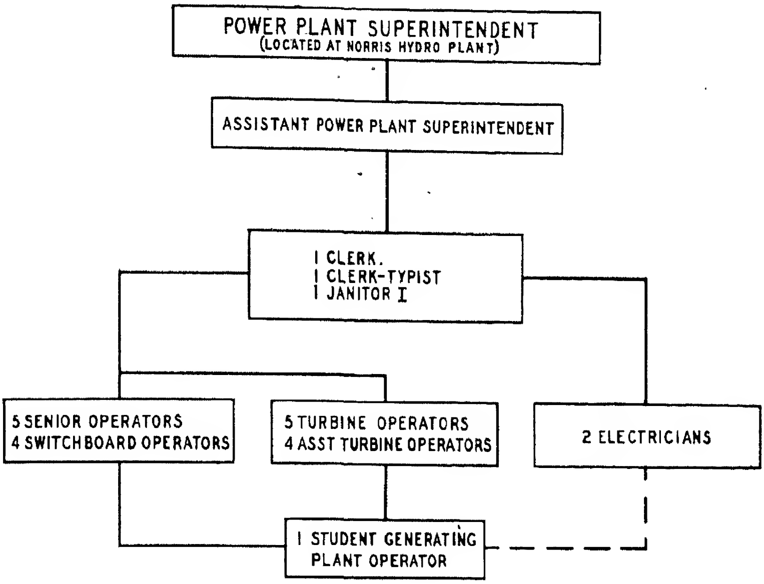

FIGURE 150.—*Organization for dam and powerhouse operation.*

FLOOD CONTROL

Douglas Reservoir, since closure of the dam in February 1943, has been operated to advantage in the control of four floods of substantial size at Chattanooga. Floods occurring in January 1946, January 1947, and February 1948 would have been the fifth, sixth, and seventh highest, respectively, at Chattanooga if they had not been reduced by the reservoir system. Although not as large, a flood in March 1944 also would have caused considerable damage at Chattanooga.

Douglas Reservoir, in conjunction with the other tributary and main-river reservoirs, was operated to reduce these flood crests and the resulting damage downstream. Flood crests along the lower French Broad River and at Knoxville were also substantially reduced by Douglas Reservoir, and reductions of lesser amounts were effected farther downstream.

The tabulation which follows gives the actual and natural crest stages at Chattanooga and the reduction in stage and damage afforded by the entire reservoir system since the operation of Douglas Reservoir.

Flood	Actual crest stage	Natural crest stage	Stage reduction	Damage reduction
	Feet	*Feet*	*Feet*	
March 1944	31.7	37.8	6.1	$300,000
January 1946	35.7	45.8	10.1	11,960,000
January 1947	31.8	44.5	12.7	11,700,000
February 1948	33.8	44.3	10.5	13,240,000

NAVIGATION

Douglas Reservoir was filled late in the winter of 1942–43, creating a slack-water channel 43.1 miles in length along the French Broad River at normal maximum pool elevation 1000. This channel extends from the dam, which is at mile 32.3, to a point just below Newport, Tenn., on the French Broad, and for a distance of about 8 miles up the Nolichucky River.

No navigation lock was included in the project, and the reservoir is thus an isolated canalized section of the river available for local commercial traffic and use by small craft only. The natural river below and above the reservoir was heavily shoaled, and its tortuous channel and swift waters were not navigable by modern commercial tows.

In 1940 TVA conducted studies of 10 of the more important navigable tributaries of the Tennessee to determine whether future improvements on these tributaries should include provisions for navigation facilities. Although preliminary in nature, these studies indicated clearly that potentialities for through traffic between points in or above the reservoir and the main-river navigation project were not sufficient to warrant inclusion of a lock and other navigation facilities in the Douglas project.

It was brought out that the population centers, industries, and resources which would be benefited by a French Broad River navigation development also fell within the area which would be tributary to a similar development on the Holston River, and that the total traffic potentialities of the latter were considerably greater. Accordingly, it was recommended that navigation facilities not be included in French Broad River projects.

Through 1947, navigation in the Douglas Reservoir had consisted only of use by recreation craft and by TVA malaria control and other reservoir operating craft. Local commercial movements of forest products or other commodities are considered possibilities, however. Accordingly, bridge and wire crossings over the main body of the reservoir were raised or rebuilt to provide secondary channel vertical clearances and minimum horizontal clearances to 100 feet. (See discussion under "Navigation preparation" in chapter 6.) All subsequent construction of reservoir crossings has been required to be of similar order.

MALARIA CONTROL

Clearing for malaria control was performed mainly in the shallow marginal areas within the upper 10-foot zone to provide a clean shore line and water surface where anopheline mosquito breeding occurred. This work was in accordance with the TVA's specifications which were based upon regulations of the Tennessee Department of Public Health. Marginal drainage was provided through eight drainage projects in areas lying between the 992 and 1,002 contours where drainage of ponds and swampy areas would eliminate or lessen the post-impoundage mosquito-control problem.

Prior to impoundage, removal of coppice, weeds, vines, cornstalks, and other herbaceous growth between the 992- and 1,002-foot contours was undertaken. Fifteen preimpoundage mosquito-catching stations

were located within the reservoir to determine the kind and extent of mosquito production. It was found that very little mosquito production was occurring along the margins.

For postimpoundage operations, boat-operating bases were constructed at Shady Grove and Oak Grove, providing immediate access to the areas requiring larvicidal treatment. Wooden floating boat slips were placed at each base, and a small storage house, gasoline tank and pump, larvicidal storage tanks, and sanitary toilet facilities were provided on the shore.

Impoundage was begun in March 1943, but because the reservoir was not entirely filled, there was a comparatively heavy shore line growth in the spring and early summer. A marginal growth removal program was begun in July 1943, but because of the considerable extent of the program and the rapid turn-over of personnel, it was impossible to complete it prior to the end of the calendar year.

RESERVOIR WATER INVESTIGATIONS

Ground water studies

Investigations were made of lands adjacent to the reservoir where it appeared likely that claims related to ground water conditions or backwater damage might arise. A number of ground water wells and crest markers were installed before the reservoir was filled, and regular observations were continued until July 1945.

A census was made of 248 domestic wells on land adjacent to the reservoir, and information was collected regarding the name of the owner, and the elevations of ground surface, bottom of well, and water surface. Samples of water for mineral analysis were obtained from a number of these wells to determine if any change occurred in water characteristics after the dam was completed.

A special investigation was made at Dandridge, Tenn., to determine whether the construction of a dike to protect the town might raise ground water levels sufficiently to affect basements.

Leakage investigations

The possibility of leakage from the reservoir was investigated early in 1942. A number of points below the dam were selected for regular inspection, and a stream gage was installed on Millican Creek. This stream parallels the south reservoir rim. Stream gage records since closure of the dam do not show any increase in flow attributable to water coming through the reservoir rim area.

Twenty-seven permanent ground water holes were drilled by construction forces below the north embankment and along the south reservoir rim to determine the effect of reservoir fluctuations on ground water levels below the dam. Regular observations have been made on these wells, and also on four weirs installed by construction forces in 1943 below saddle dam No. 1. Weekly to biweekly measurements have been made of total flow in the drainage gallery in the dam, supplemented by monthly measurements of flow from each of the foundation drain holes. Total foundation drainage at high pool, as measured in the gallery, decreased from about 60 gallons per minute in 1943 to from 10 to 20 gallons per minute in 1947.

In April 1943, when construction on the Dandridge dike was nearing completion, a minor seepage condition developed below the land-

ward toe near the south end of the dike. A careful investigation was made of this situation and a permanent recording weir was installed to measure the amount of the flow. Regular observations made whenever the reservoir was high enough to produce seepage show a progressive decrease in seepage flow from year to year at equivalent pool stages. In June 1946 the seepage had decreased to a negligible quantity of less than 2 gallons per minute.

Evaporation studies

Closely allied with rainfall data are those related to evaporation from land and water surfaces. In December 1941 an evaporation station was installed at Carson-Newman College, in Jefferson City, Tenn., for measurement of evaporation from a standard land pan. The station observations include air and water temperatures, wind velocities, relative humidities, and barometric pressures. Annual evaporation for the four complete years 1942 to 1945 averaged 43.5 inches, of which 55 percent occurred during the months from May to August, inclusive. The maximum yearly amount was 45.9 inches in 1944, and the maximum monthly evaporation was 8.15 inches in June of the same year.

Reservoir and river temperatures

Observations of water temperatures in Douglas Reservoir are being made monthly at four verticals between the dam and U. S. Highway No. 25E bridge. In addition, water temperature recorders have been installed at the bridge below the dam and above the head of backwater on French Broad, Nolichucky, and Pigeon Rivers. Information on inflow temperatures and temperatures at various levels in the reservoir is useful to industries and in recreational, biological, and stream pollution studies. Water at the lower levels is particularly valuable to industries requiring water for cooling purposes. During the summer months such water is about 30° cooler than that at the reservoir surface or in nearby flowing streams.

Water analyses

During the year May 1936 to May 1937, weekly samples of water were collected for mineral and pollution analyses from the French Broad River just above its mouth, 32 miles below Douglas Dam. During the year August 1937 to August 1938, similar samples were collected weekly from the Nolichucky River below Greeneville, the French Broad River near Newport, and the Pigeon River above Newport.

A considerable number of mineral analyses of water from domestic wells located near the shores of the reservoir have been made in connection with other studies being made to determine whether or not the filling and existence of the reservoir caused any damage to such wells. Among these wells were several located in Dandridge. In connection with these studies a number of analyses of reservoir water were also made.

SILT INVESTIGATIONS

The TVA has carried out an extensive program of silt investigations in order to determine the reduction in reservoir capacity by silt deposition and the effect of silting in navigation channels. In addi-

tion, intensive investigations have been made on selected small watersheds to obtain data on loss of fertile topsoil, and to determine the efficacy of various protective measures in reducing erosion and silting. From 1934 until 1942 silt samples were collected from a number of points on the Tennessee River and its major tributaries and were analyzed in order to arrive at a relationship between flow and silt load. With these data it is possible to estimate the number of years required to fill the various reservoirs.

The progress of reservoir sedimentation is determined by periodic sounding of selected ranges throughout each reservoir and by comparison of these soundings with the original cross sections.

Reservoir silting.—Studies of reservoir characteristics and determinations of the silt load of the French Broad River indicate that Douglas Reservoir will fill to minimum operating level, elevation 940, in about 180 years. Silting to the top of the spillway gates, elevation 1002, will require an estimated 1,200 years.

Before Douglas Reservoir was filled, 48 silt ranges were selected and cross sectioned to serve as basic data for the determination of the progress of silt deposition. These ranges extend up the main river from the dam to the mouth of Pigeon River and up the various tributaries to the head of normal backwater.

FORESTRY

Reforestation, erosion control, and forest management

Of the 2,400 acres of land acquired in fee title above pool within the Douglas Reservoir area, it is estimated that some 1,000 acres are forested. The remainder is agricultural acreage, generally of such condition as to present no immediate soil-erosion problem.

Since most of the forest acreage is located in segregated units on inaccessible islands or peninsulas, it is not expected that the timber resources will be of appreciable economic significance as compared to other reservoir properties in the custody of TVA. However, these resources will be managed in keeping with sound management practices for local demonstration and community education. Considerable forest acreage is within or contiguous to proposed recreational use areas and will be considered in protection plans and measures to conserve and enhance the recreational values.

FISH AND GAME

Fisheries

Douglas is a storage reservoir relatively deep and with steep shore lines. It is subject to a severe annual draw-down. These physical and operational features all contribute toward a lower productivity as compared with main-stream reservoirs. Douglas Reservoir has a fish population very similar to that found in Norris—the black basses, the pike, crappies, various sunfish, and the usual river-run of food and rough fish species. Since the physical and operational features of Douglas are in all respects very similar to Norris, fish production may likewise be expected to be very similar; that is, periodically there should be good sport fishing. The rough fish, such as carp, should show a decline after the first few years of impoundment. If this com-

parison with Norris Reservoir is valid, fishing in Douglas should be at least 40 times as heavy as it was in the original river.

Because of the shape of the reservoir, and because of the relatively large volume of water moving through it, this body of water is subject to an atypical vertical stratification with respect to dissolved oxygen turbidity during the summer. This atypical stratification is the result of density currents. Experience on Norris Reservoir has shown that this atypical stratification of the water causes a redistribution of the fishes with respect to depth and this, together with the relatively great depth of the reservoir, affects the kinds of fish and leads people to believe that fish are scarce when they are merely difficult to locate.

No fish cultural facilities are contemplated for this reservoir because it is felt that natural propagation will maintain desirable fish populations.

Game

The development of small game—quail, doves, rabbits, squirrels, and such fur bearers as raccoon and opossum will depend very largely on agricultural and forestry practices. Muskrats will be affected adversely by the severe winter draw-down.

Migratory waterfowl.—Because of wide fluctuation in water level resulting in the absence of aquatic vegetation the possibilities for migratory waterfowl are limited.

AGRICULTURE

The TVA acquired approximately 33,050 acres of land for this project of which about 28,100 acres were below and 4,950 acres were above the maximum operating level of the reservoir. Contrary to the policy followed in other major storage reservoirs, most of the acquisition was by flowage easement rather than by fee purchase. Adoption of this policy resulted in the acquisition of very little land not subject to flooding and left in private ownership portions of more than half of all land tracts affected by the reservoir. Retention of these remnants permitted owners to make temporary readjustments rapidly and materially lessened the total loss in agricultural production.

In this reservoir TVA acquired fee title only to about 2,330 acres of land not subject to flooding and most of this acreage was either not suitable for agricultural use or was required for some other purpose. For this reason the usual arrangements whereby organized groups of farmers advised and assisted in the development of plans for agricultural use of TVA controlled land were not entered into and the very limited areas available were licensed by TVA upon informal advice of local agricultural extension service representatives.

A fairly large acreage of the fertile river bottom land acquired by TVA had been used for the production of vegetables for canning in two nearby commercial plants. The loss of this production was serious and raised some question as to whether or not these plants could get the agricultural products necessary to permit continued operation. In order to determine the extent to which commercial vegetable production might be maintained in the area, arrangements were made for the University of Tennessee to conduct some research in the production of vegetables on soil types common in the area.

Irrigation was an important part of the research and results have been very helpful to farmers in determining the uses which could be made of land to provide maximum returns to the operator and at the same time help provide the raw materials necessary to support local processing plants employing a large number of people.

RECREATION

Douglas Lake, lying in the valley of the French Broad River along the foothills of the Great Smoky Mountains, supplies this scenically attractive region with new and important recreational opportunities. Although the lake lies close to a recreational area of national importance, its completion during wartime was not immediately followed by recreational development along the shore line. This general region is agricultural, containing none of the metropolitan centers lying so close to other lakes of the TVA system.

Major routes of tourist travel between the Southern Highlands and Northern States cross Douglas Lake at strategic points. Many travelers are thus attracted to this vicinity for vacationing purposes. Douglas Lake, because of its location and scenic mountainous setting will eventually become a most important recreational factor in this region.

The immediate setting of Douglas Lake is a series of low slate knobs, with parallel minor ridges and valleys which make up the valley of east Tennessee. To the south are the Great Smoky Mountains and, in the foreground, English Mountain serving as a backdrop, and contributing great scenic beauty to the lake. The Great Smoky Mountains rise even higher than English Mountain, but at a greater distance southward, and being visible from all sections of the lake, contribute to the mountainous aspect of the region. The main shore line of the lake, exclusive of islands, is 492 miles at normal maximum pool level.

In view of the need for intensive use of all available agricultural land in the immediate vicinity, TVA considered it unwise to purchase more of the lake shore line than was required to meet absolute minimum requirements for public access. For this reason, lands now available for recreational development and use are confined to a relatively few small areas. These are strategically located with respect to centers of population and main arteries of highway travel, and will provide for a variety of recreational uses for both local residents and tourists.

The water level of the lake is subject to a maximum possible fluctuation of 82 feet. During a normal year, however, fluctuation is not expected to exceed 67 feet. Although this draw-down to some extent mars the beauty of the lake, it generally occurs during the winter months when it will not seriously hamper recreational development. The anticipated disadvantages are offset somewhat by convenient access from existing travel routes and the beauty of its surroundings. These disadvantages can be offset further by the provision of adequate recreational facilities and the maintenance of high standards of service and accommodations.

In addition to providing a new recreation resource for residents of the lake area, Douglas Lake is attracting many tourists and nonresident

vacationists. The scenic attractions of the Great Smoky Mountains National Park have long been tourist objectives. For the past 10 years this park has been visited either by more tourists than any other national park, or has ranked second only to the Shenandoah National Park. The shores of Douglas Lake form an ideal setting for resort hotels, vacation cottages, and other similar accommodations for tourists to the Smoky Mountains area. Projected access roads and parkways will tend to facilitate access between the park and the lake. Although it is expected that Dandridge, the only incorporated town directly on the lake shore, may become the principal recreation service center for the lake, communities such as Newport, Sevierville, and Chestnut Hill should also benefit directly from increased tourist trade. Development of a lake-shore park by the town is stimulating Dandridge as a recreational service center.

Although TVA, in cooperation with the Tennessee Department of Conservation, formulated the comprehensive plan for use of its Douglas Lake properties, actual development of recreational areas and facilities is being carried on by citizens of the region either directly or through the appropriate branches of their state and local governments. Only in the immediate vicinity of the dam and powerhouse, where it is the obligation of TVA to undertake such public developments as may appear desirable, does TVA function both as planner and effectuating agent of recreational developments. While local public agencies can be expected to undertake the sponsorship of a limited number of public recreation areas, such as the park at Dandridge, no state parks are planned on the lake shore. It is also improbable that federal agencies, such as the United States Forest Service or the National Park Service, will extend their spheres of influence from the mountains to include portions of the lake shore. To a large extent, therefore, recreational development on Douglas Lake is dependent upon private initiative.

As at other TVA projects completed since the outbreak of war, the development of TVA-owned land in the immediate vicinity of the dam and powerhouse was deferred until the postwar period. Tentative plans call for the construction of an overlook building, provision of picnic facilities, and other accommodations for the visiting public. In the powerhouse, at the north end of the dam, visitors' accommodations will include a reception room and information display, toilets, and an observation gallery overlooking the generator room.

TVA reservoir lands available for recreational development and use have been classified in accordance with their location, size, potential value, and in relation to the estimated needs and probable abilities of developing agencies or organizations. The following sections generally divide developmental responsibilities among public agencies, quasi-public groups, and individuals.

Public sponsorship development areas

Included in this classification are those areas large enough to permit recreational developments to serve the general public, such as county and municipal parks. The Tennessee Department of Conservation has expressed an interest in opportunities for supplementing the state park system through the development of public-use areas in this section of the state, by local public agencies—county or city.

Flat Creek recreation area.—This area of some 90 acres, lying just upstream from the south abutment of Douglas Dam at the mouth of the Flat Creek embayment, offers excellent opportunities for the development of a public recreation area. Access to the lake shore line over good roads provides Sevier County and Sevierville with opportunities for recreation in the scenic lower reservoir area. Sponsorship of a development by Sevier County eventually may provide desirable protection to the natural scenic values in this vicinity and is expected to form the nucleus for a larger park area of some future importance in this section of Tennessee.

Directly across the embayment is a long, narrow peninsula containing approximately 156 acres suitable for development as a group camp area. In the event this area could be included within the Flat Creek recreation area development, the joint efforts of Sevier and Jefferson Counties would be advantageous and in the public interest. The group camp area is primarily suitable for quasi-public sponsorship.

Southbridge Park area.—Approximately 85 acres of TVA land on the south side of the lake, opposite Dandridge, are under lease to the city for park development. An island of some 40 acres, at the south abutment of the relocated Dandridge Bridge, has been connected to this portion of the mainland by the highway approach fill, creating an excellent harbor area west of the highway.

Although the island is nearly bare of trees, the excellence of the harbor and its accessibility over the relocated Dandridge-Chestnut Hill Road indicate the importance of the area for future recreational use. Sponsorship of this attractive area by the city of Dandridge insures the development in the future of adequate public-use recreation facilities at this strategic point, about midway on Douglas Lake.

Quasi-public development areas

Three selected areas along the shores of the lake are considered suitable for the special use of organized camping groups or organizations for vacation and recreation programs.

Flat Creek group camp area.—This land, previously mentioned in connection with the Flat Creek public sponsorship recreation area, is isolated from access by road and ideal for organized camp use. Its approximate 156 acres could be developed separately or in conjunction with the potential public-use area. Considerable demand for group camp locations is expected to develop in Sevierville and near-by communities near the lower end of the lake, especially in view of the importance of the recreational resources represented in this reservoir and the relatively small acreage available for such public use.

Sandy Ridge group camp area.—The western portion of this area, located near the village of Sandy Ridge and accessible from the Dandridge-Chestnut Hill Road, is suitable for group camp use and development. This area is composed of a series of small, partially wooded peninsulas, forming a larger peninsula which juts into the Muddy Creek embayment and commands views southward to English Mountain. The approximately 35 acres of land available here would provide the south shore of the lake with an important group camp site in the vicinity of Newport.

Indian Creek group camp area.—The peninsula between Muddy Hollow and the Indian Creek embayment is accessible from a relocated county road. The area is relatively remote, consisting of a number of partially wooded knobs or ridges extending up to 140 feet above the normal pool level of the lake. The site, of approximately 40 acres, provides superb views and is sufficiently large to permit organized camping development.

Private development areas

Areas of TVA land available for private development on Douglas Lake are limited to fishing camps and boat docks. This is primarily due to the restrictions upon the purchase of land in this rich agricultural section. Eleven areas, totaling approximately 267 acres, have been designated as suitable for this type of development. Two of these areas are in Sevier County, one in Cocke County, and the remainder in Jefferson County. The largest of these, the Millican area in Sevier County, contains 113 acres which are available for the development of a fishing camp with related facilities. This area is located east of the Millican community and is at the nearest accessible point on the lake to Sevierville and the Great Smoky Mountains National Park. This cove has been prepared for the use of pleasure boats and a boat-landing ramp has been provided. Considerable use of this site is anticipated, especially during the summer recreational season when the lake is somewhere within the normal levels.

The second largest is the Tryon area totaling some 45 acres on two peninsulas on both sides of the Indian Creek Gap in Jefferson County. This rather rugged, partially forested area is suitable for cabins for overnight occupancy, or for related uses, and is potentially important for the development of a fishing camp and boat docks in view of the relatively easy access to the site from the vicinity of Newport.

The Frye Branch area, totaling approximately 34 acres on three peninsula tips of land surrounding the embayment just east of Shady Grove in Jefferson County, is available for a boat dock adjacent to the highly traveled Dandrige-Douglas Dam Road. This is the only such site between these two points along the north shore of the lake which is available for this use. Its prepared harbor, plus excellent accessibility to the shore line, indicates the future importance of the site for a commercial boat-dock development for recreational purposes.

Sizes of the remaining eight areas range between 22 and 3 acres. All were selected for possible private development of fishing-camp and boat-dock facilities because of their locations in relation to centers of population not otherwise served, easy public access, prepared harbors, and scenic surroundings.

In addition to the areas listed, certain other areas on Douglas Lake have potential values for public use.

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CHAPTER 8

COSTS

Immediately upon authorization of this project, accounts were opened by the Cherokee project office. Two months later, when quarters were available, an accounting office was established at the Douglas project site.

The accounting office was responsible for all accounting and cost work in connection with the construction of the project. Field offices were established at Morristown, Tenn., to handle payrolls and warehouse operations in connection with reservoir clearing operations, highway and railroad relocation activities, and backwater protection work. These costs were currently incorporated in the project accounting records.

Organization and division of work

The project accounting office was responsible for the maintenance of all accounts and financial records for the project and included general accounting, cost accounting, bookkeeping, timekeeping and payrolls, warehouse operation and accounting, collection of and reporting cash receipts, record of disbursements, shop accounting, preparation of financial and cost statements, accounting for operation of employee housing, preparation of final project cost report, and development of data for establishment of continuing plant records for the project. Supervision of these functions was exercised by the project accountant through section heads which were: the accountant in charge of accounting and timekeeping; the cost engineer in charge of cost and related work; the chief storekeeper in charge of receiving, storing, and issuing materials; the respective chief clerks of the reservoir clearance and the construction and maintenance divisions located on the project.

Accounting

Bookkeeping entries were made from documents such as public voucher for purchases and services other than personal, journal vouchers, shipping tickets, invoices issued, cash collection reports, and shop orders, describing the nature of the item, the document number, and amount. These entries were made with the use of an accounting machine. Each ledger sheet account was made in triplicate. A new sheet was opened for every account at the beginning of each month, thereby making it possible to simultaneously close the accounts of one month, to prepare trial balances, and to start the next month's entries. Since departmental budgets of the TVA are prepared in terms of objects of expenditures, as well as in terms of purposes for which expenditures are made, separate object-of-expenditure ledger sheets were set up to record expenditures, identified and grouped to show income and expenditures according to the nature of the service or articles involved and by organizations. Totals on cost account ledger sheets were balanced by organizations with totals on object-of-ex-

penditure ledger sheets eliminating the necessity for maintaining other control accounts for the cost account ledger sheets. Monthly financial reports were prepared directly from the ledger sheets and consisted of trial balance, organization statements, and objects-of-expenditure report.

Public voucher for purchases and services other than personal.—Invoices were received by the accounting office, dated, verified, and checked against proper purchase order and/or contract. Receiving reports were prepared by the warehouse and forwarded to the accounting office with delivery tickets, freight bills, and, if applicable, over, short, and defective reports and formed the basis of final acceptance of the charge. Vouchers were then prepared and forwarded to the Knoxville office for payment. The accounting office retained one copy of the voucher complete with supporting documents which after entry was filed numerically by months and one copy of the voucher, with no supporting papers, which was filed alphabetically.

Journal vouchers.—Payroll distributions, warehouse issues, machine time distribution, clearing account distribution, transfers from other offices and corrections and adjustments were summarized on journal vouchers. These vouchers were filed numerically by months with supporting papers attached with the exception of warehouse issues and machine time distribution vouchers. Warehouse issue requisitions were filed by account number by months and machine time reports were filed by machines by months.

Shipping tickets.—Incoming shipping tickets supported charges from other offices and were summarized on journal voucher. Outgoing shipping tickets, or those covering shipments of materials or equipment from the project were given a job filing number just prior to posting and filed numerically by this file number.

Invoices issued.—Billings to outside parties were made on an invoice form, one copy of which, with attachments, was retained for posting to ledgers.

Cash collection reports.—Reports covering cash collected principally in connection with commercial unit operations in the camp, were posted direct to ledger sheets and filed in chronological order.

Shop orders.—Cost of work done in the machine and carpenter shops was collected on individual job orders and at the end of the month posted to ledger sheets. Shop orders were then filed in numerical order.

Timekeeping

Timekeeping for hourly employees was controlled by the use of the brass check system. Each employee on reporting for work for the first time was assigned a number and given an identification badge and brass check each bearing this number. He was instructed to draw the check when reporting to work at the beginning of each shift and to drop it at the check booth when completing his work for the shift. In addition to control obtained by this method of checking starting and quitting time field time checks were made twice a day and the employee's presence was noted on the time checker's sheet. These sheets were turned over to a payroll clerk for comparison with reports turned in daily by each foreman listing the employees in his crew; the hours worked, and jobs on which each individual worked. The result of these comparisons formed the basis for payment of hourly employees.

Time was posted to individual employees ledger sheets from these records, and payrolls were prepared from the ledger sheets. Time of annually rated employees was obtained from monthly time sheets, approved by their immediate and general supervisors. In connection with payroll preparation the time office was charged with responsibility for making various payroll deductions such as tax, retirement, medical care, dormitory rent, cafeteria meals, and cash advances.

Cost engineering

This unit established and maintained a job classification of accounts in accordance with requirements of the master classification of construction accounts; set up the total budget at the beginning of construction from information obtained from construction schedules, the original estimates and the job classification of accounts; prepared monthly budget studies to incorporate quantity and cost changes as the work progressed and prepared fiscal year budget based upon the original budget as modified by changes in both the construction schedules and actual costs. They established routines for the collection of field data such as: use of electricity, water, compressed air and other clearing accounts to enable monthly clearances of these facilities; informed the field and office engineers of data required for distribution of costs such as cofferdam, excavation, and concrete; prepared requests for inventory to be obtained from the field and office engineers for preparation of cost and final plant records reports; coded all labor, materials, machine time and shop costs; established use rates for machine time, checking periodically for correctness; prepared periodic cost analyses for the information of job management; currently prepared analyses of accounting records and on completion of work reconciled these records with final inventory data furnished by the engineers. From these reconciliations were prepared the final cost and plant records report.

Warehousing

The procedure for securing materials began with the designated foremen or supervisors preparing a request for purchase, listing and describing the desired materials or services. After proper account number had been added, the request went to the warehouse where a purchase requisition was written and forwarded to proper offices for signature and certification. The requisitions for construction materials and equipment were approved by the construction superintendent. Those for permanent equipment or materials were approved by the construction engineer. In general, only requisitions covering expenditures for more than $2,000 were approved by the project manager. The requisitions were then forwarded to the TVA's purchasing organization which handled the purchases through the regular procedures as established by the TVA Act. Upon delivery, receiving reports were prepared, checked with purchase order, and when shipment was complete, forwarded to the accounting office.

Receipt of material involved proper tagging and storage and entry on stock ledgers if material was an inventory item. If not an inventory item, it was tagged and stored pending need by originator of request for purchase. To account for these latter items, the warehouse kept a ledger showing requisition, purchase order, description of items,

location in the warehouse, date of withdrawal and name of person making withdrawal.

A record was kept of all inventory material issued to the job, describing the use for which the material was intended, listing the items issued, and was signed by the issue clerk and the receiver. These were accumulated monthly, priced by the accounting office, and clearance from inventory accounts was made to cost accounts by journal vouchers.

All material leaving the project was listed on shipping tickets. These were prepared in the warehouse and transmitted to the accounting office where billing was made against receiving agency. Receipt for incoming material from other sections of the TVA was effected through completion of the inspector's copy of the shipping ticket and preparation of receiving reports.

All collect freight shipments were made on Government bills of lading. Carriers rendered freight bills showing the bill of lading number and accepted the "accomplished" copy of the bill of lading in lieu of payment. Settlement for freight charges was made by the accounting office in Knoxville after audit by the General Accounting Office in Washington. The liability for the transportation charges was recorded, through field voucher.

SUMMARY OF COSTS

The final cost of the original Douglas project, as reported herein at $40,244,348.87 (General Summary, p. 333), and as reflected by the books of account at June 30, 1945, includes hydraulic multiple-purpose plant consisting of land, land rights, structures, improvements, and equipment; transmission plant consisting of the primary substation located at the dam site and constructed concurrently with the dam; and general plant comprising intersite communication equipment.

The final cost of the project by character of expenditures is as follows:

Land costs		$6,877,233.41
Construction costs:		
Direct construction costs	$28,443,141.10	
Indirect construction costs	1,946,625.97	
		30,389,767.07
Distributive general expense:		
Design and construction engineering	1,312,736.58	
Executive and administrative costs	1,310,324.89	
Other general costs	354,286.92	
		2,977,348.39
Total		40,244,348.87

Land costs amounting to $6,877,233.41 cover reservoir land acquired in fee or by certificate of taking in condemnation proceedings; reservoir flowage easements; and easements for relocation of highways, railroads, and public utilities.

Direct construction costs totaling $28,443,141.10 are for labor, material, construction plant, equipment, tools, shop expense, warehouse charges, transportation, and other similar expenditures.

Indirect construction costs amounting to $1,946,625.97 include field superintendence, accounting, cost engineering, timekeeping, personal travel and subsistence of employees on official business, office supplies and expense, construction plant studies and design, police and guide

service, temporary access roads and railroad, camp operation, and cost incurred in obtaining equipment originally ordered and delivered to other construction projects, to permit earlier operation of the Douglas project (p. 352). These indirect construction costs have been distributed to their related direct construction costs.

Design and construction engineering costs total $1,312,736.58 and include salaries and expenses of field and executive supervisory engineers, concrete technicians and inspectors; engineering for control lines and bench marks; general examination, studies and reports on proposed dam sites and effect of dam construction on sinks, wells, and springs in the reservoir area; design of all permanent structures, including highway and railway relocations; and landscape treatment at dam site (p. 353). These costs have been distributed on the basis of related construction costs, that is, relocation engineering to relocation work, and dam, powerhouse, and switchyard engineering to dam, powerhouse, and switchyard structures and equipment.

Executive and administrative costs in the amount of $1,310,324.89 consist of the Douglas project's proportion of the total departmental and general administration of the Tennessee Valley Authority (p. 353). These costs have been prorated over all accounts exclusive of purchase price of land.

Other general costs amount to $354,286.92 and consist of such expenses as reservoir and dam-site mapping; pro rata share of the cost of collection and compilation of basic hydrographic and hydrologic data; project and regional planning studies; construction medical service; personnel and training department services; and the preparation of a final project report (p. 353). These costs have likewise been distributed over all accounts exclusive of purchase price of land.

Summary statements of detailed analyses of costs are presented in the schedules which follow.

TABLE 42.—*Final project cost—general summary*

Account	Description	Amount
	HYDRAULIC MULTIPLE-PURPOSE PLANT	
20	Land and land rights	$14, 853, 842. 67
21	Structures and improvements	3, 364, 416. 56
22	Reservoirs, dams, and waterways	18, 303, 237. 98
23	Water wheels, turbines, and generators	2, 147, 898. 90
24	Accessory electric equipment	411, 345. 55
25	Miscellaneous power-plant equipment	395, 214. 66
27	Village and reservoir facilities	21, 028. 35
		39, 496, 984. 67
	TRANSMISSION PLANT	
42	Structures and improvements	287, 518. 94
43	Station equipment	418, 553. 04
		706, 071. 98
	GENERAL PLANT	
78	Communication facilities	42, 296. 80
		42, 296. 80
		40, 245, 353. 45
	Deduct: Reserves on permanent equipment transferred from other projects	1, 004. 58
	Total	40, 244, 348. 87

TABLE 43.—*Final project cost—detail summary*

	Item	Land costs	Direct construction costs; labor, material, and other charges	Indirect construction costs	Total: Land, direct and indirect construction costs	Distributive general expense: Design and construction engineering	Distributive general expense: Executive and administrative costs	Distributive general expense: Other general costs	Total
	HYDRAULIC MULTIPLE PURPOSE PLANT								
	Land and land rights:								
200	[illegible]	[illegible]	$35,436.29	$3,136.34	$6,398,147.20		$1,571.14	$424.81	$6,400,443.15
201	[illegible]	[illegible]			399,842.05		16,285.36	4,403.52	420,531.93
204	[illegible]	[illegible]	4,905,851.79	64,366.38	5,084,111.80	$280,031.37	216,422.07	58,516.42	5,639,081.66
205	[illegible]	[illegible]	1,788,035.20	25,904.62	1,816,650.14	73,127.66	76,955.10	20,807.48	1,987,550.38
207	Relocating other structures and improvements	903.84	338,790.21	2,981.84	342,675.89	43,580.53	15,728.88	4,252.25	406,235.55
		6,377,233.41	7,068,113.49	96,389.13	14,041,736.08	396,739.56	326,962.56	88,404.48	14,853,842.67
	Structures and improvements:								
212	General yard improvements		288,469.69	25,317.41	313,787.10	12,115.50	13,274.65	3,589.22	342,766.47
213	Powerhouse		2,085,253.73	186,649.25	2,271,902.98	89,319.91	96,177.29	26,004.51	2,483,404.69
215	Intake		446,805.36	39,993.16	486,798.52	19,138.49	20,607.88	5,571.90	532,116.79
216	Miscellaneous buildings		5,146.05	460.61	5,606.66	220.43	237.35	64.17	6,128.61
			2,825,674.83	252,420.43	3,078,095.26	120,794.33	130,297.17	35,229.80	3,364,416.56
	Reservoirs, dams, and waterways:								
220	Reservoir		927,785.98	82,541.74	1,010,327.72	65,966.46	43,839.59	11,853.40	1,131,987.17
221	Concrete dam and spillway		11,936,046.05	1,073,755.63	13,009,801.68	513,839.53	553,288.59	149,598.74	14,226,528.54
222	Auxiliary dams		1,772,986.82	98,381.72	1,871,368.54	51,190.37	78,309.64	21,173.43	2,022,041.98
223	Water conductors		724,371.39	64,837.86	789,209.25	31,027.77	33,409.87	9,033.40	862,680.29
			15,421,190.24	1,319,516.95	16,740,707.19	662,024.13	708,847.69	191,658.97	18,303,237.98
	Water wheels, turbines, and generators:								
230	Foundations and miscellaneous steel and iron		3,373.46	301.95	3,675.41	144.50	155.59	42.07	4,017.57
231	Turbines, including scroll case, speed ring, and draft tube liners		746,173.09	66,789.31	812,962.40	31,961.63	34,416.43	9,305.28	888,644.74
232	Auxiliary equipment for turbine		97,104.84	8,691.77	105,796.61	4,159.40	4,478.73	1,210.96	115,645.70
233	Draft tube gates		53,047.56	4,748.24	57,795.80	2,272.24	2,446.69	661.54	63,176.27
235	Generators		862,241.27	77,178.47	939,419.74	36,933.30	39,768.79	10,752.73	1,026,874.56
236	Auxiliary equipment for generator		23,049.12	2,063.11	25,112.23	987.29	1,063.08	287.44	27,450.04
239	Miscellaneous equipment for turbine and generator		18,548.45	1,660.25	20,208.70	794.51	855.50	231.31	22,090.02
			1,803,537.79	161,433.10	1,964,970.89	77,252.87	83,183.81	22,491.33	2,147,898.90
	Accessory electric equipment:								
241	Switchgear		50,751.05	4,542.68	55,293.73	2,173.88	2,340.77	632.90	60,441.28
242	Switchboards		129,367.60	11,579.58	140,947.18	5,541.34	5,966.77	1,613.30	154,068.59
243	Protective equipment		12,618.29	1,129.45	13,747.74	540.49	581.99	157.36	15,027.58
244	Electrical structures		8,467.27	757.90	9,225.17	362.69	390.54	105.59	10,083.99
245	Conduit work		55,157.93	4,937.14	60,095.07	2,362.64	2,544.02	687.86	65,689.59
246	Power and control wiring		29,408.59	2,632.34	32,040.93	1,259.69	1,356.40	366.74	35,023.76
249	Station service equipment		59,625.99	5,337.07	64,963.06	2,554.02	2,750.10	743.58	71,010.76
			345,396.72	30,916.16	376,312.88	14,794.75	15,930.59	4,307.33	411,345.55
	Miscellaneous power plant equipment:								
252	Station maintenance equipment		8,955.25	801.58	9,756.83	383.59	413.04	111.68	10,665.14
255	[illegible]		280,468.96	25,104.53	305,573.49	12,013.63	12,935.95	3,497.64	334,020.71
256	[illegible]		9,106.33	815.10	9,921.43	390.06	420.01	113.56	10,845.06
258	[illegible]		5,270.71	471.78	5,742.49	225.76	243.10	65.73	6,277.08
259	[illegible]		28,050.76	2,510.80	30,561.56	1,201.53	1,293.77	349.81	33,406.67
			331,852.01	29,703.79	361,555.80	14,214.57	15,305.87	4,138.42	395,214.66
	Village and reservoir facilities:								
271	Reservoir operation facilities		19,993.77		19,993.77		814.39	220.19	21,028.35
			19,993.77		19,993.77		814.39	220.19	21,028.35
	Total hydraulic multiple-purpose plant	6,877,233.41	27,815,758.85	1,890,379.61	36,583,371.87	1,285,820.21	1,281,342.07	346,450.52	39,496,984.67
	TRANSMISSION PLANT								
	Structures and improvements:								
422	General yard improvements		169,226.77	15,147.34	184,374.11	7,248.67	7,805.17	2,110.37	201,538.32
424	Outdoor substation structure		72,195.80	6,462.19	78,657.99	3,092.44	3,329.86	900.33	85,980.62
			241,422.57	21,609.53	263,032.10	10,341.11	11,135.03	3,010.70	287,518.94
	Station equipment:								
431	Switchgear		111,914.53	10,017.37	121,931.90	4,793.76	5,161.79	1,395.65	133,283.10
432	Switchboards		519.29	46.48	565.77	22.24	23.95	6.48	618.44
433	Protective equipment		16,144.88	1,445.12	17,590.00	691.55	744.04	201.34	19,227.53
435	Conduit work		33,770.10	3,022.73	36,792.83	1,446.51	1,557.56	421.14	40,218.04
436	Power and control wiring		40,654.72	3,638.97	44,293.69	1,741.41	1,875.09	507.00	48,417.19
438	Main conversion equipment		132,864.88	11,892.62	144,757.50	5,691.14	6,128.09	1,656.89	158,233.62
439	Station service equipment		15,580.28	1,394.57	16,974.85	667.37	718.60	194.30	18,555.12
			351,448.68	31,457.80	382,906.54	15,053.98	16,209.72	4,382.80	418,553.04
	Total transmission plant		592,871.25	53,067.39	645,938.64	25,395.09	27,344.75	7,393.50	706,071.98

TABLE 43.—*Final project cost—detail summary*—Continued

Item	Land costs	Direct construction costs; labor, material, and other charges	Indirect construction costs	Total, Land, direct and indirect construction costs	Distributive General Expense: Design and construction engineering	Distributive General Expense: Executive and administrative costs	Distributive General Expense: Other general costs	Total
GENERAL PLANT								
Communication facilities:								
378 Communication equipment		$35, 515. 58	$3, 178. 97	$38, 694. 55	$1, 521. 28	$1, 638. 07	$442. 90	$42, 296. 80
Total general plant		35, 515. 58	3, 178. 97	38, 694. 55	1, 521. 28	1, 638. 07	442. 90	42, 296. 80
	$6, 877, 233. 41	28, 444, 145. 68	1, 946, 625. 97	37, 268, 005. 06	1, 312, 736. 58	1, 310, 324. 89	354, 286. 92	40, 245, 353. 45
Deduct:								
Reserves on permanent equipment transferred from other projects		1, 004. 58		1, 004. 58				1, 004. 58
Totals	6, 877, 233. 41	28, 443, 141. 10	1, 946, 625. 97	37, 267, 000. 48	1, 312, 736. 58	1, 310, 324. 89	354, 286. 92	40, 244, 348. 87

Table 44.—*Land costs and direct construction costs—details*

HYDRAULIC MULTIPLE PURPOSE PLANT

LAND AND LAND RIGHTS

Account	Description	Quantity	Unit	Rate	Amount
200	Purchase price of land:				
	This section of the account covers the cost of reservoir land purchased in fee and permanent easements acquired for which title rested in the U. S. Government as of June 30, 1945. Also included here is the [illegible] er with [illegible] ırts for [illegible] which [illegible] title as of June 30, 1945.				
	Land rights acquired for relocation and protection of highways, railways, and municipal facilities are included in the respective relocation accounts.				
	Reservoir land purchased in fee simple. Includes tracts in process of condemnation where title had not been transferred as of June 30, 1945 (377 tracts).	9,971.29	Acre	$181.20	$1,806,808.26
	Reservoir land rights, flowage easements (641 tracts).	23,087.50	do	197.18	4,552,351.31
	Total reservoir land and land rights	33,058.79	do	192.38	6,359,159.57
	Other land costs associated with the Douglas project consisted of right-of-way easements for a permanent communication line serving the project.				
	Communication line right-of-way easements (14,407 linear feet).	15	Tract	47.67	715.00
	This section of the account covers the cost of the demolition of buildings on land now owned by the TVA. Such buildings were purchased with the land and were located below the flow line and, therefore, had to be removed before water storage began.				
	The cost of demolition and removal of buildings.				35,436.29
	Total account No. 200				6,395,310.86
201	Expense of land and privilege acquisition:				
	Costs of acquiring land and land rights set forth in account No. 200 (33,058.79 acres).	1,018	Tract	392.77	399,842.05
	Total account No. 201				399,842.05
204	Relocating highways and highway bridges:				
-12	Bridge removal:				
-1204	Jefferson County				25,211.70
-20	State and Federal highways (6.0 miles):				
-2000	Settlement with State of Tennessee				64,910.00
-2002	U. S. Highway 25–E, French Broad River to Allen Creek				468,775.78
-2081	Swann Bridge across French Broad River and U. S. Highway 70				1,247,686.26
-2082	Walter's Bridge across French Broad River on U. S. Highway 25–E				299,431.97
	Total State and Federal highways				2,080,804.01
	County highways:				
-30	Sevier County (1.5 miles):				
-3002	Flat Creek Road, Eden Church to Gunwale Hollow				31,110.41
-3081	Bridge across French Broad River on Sevierville to Jefferson City Road at Douglas Dam				274,006.25
-3101	Sevierville to Jefferson City Road—north side of French Broad River (formerly principal access road north side, project 1001)				70,548.88

TABLE 44.—*Land costs and direct construction costs—details*—Continued

LAND AND LAND RIGHTS—Continued

Account	Description	Quantity	Unit	Rate	Amount
204	Relocating highways and highway bridges—Continued				
	County highways—Continued				
	Sevier County—Continued				
-3102	Sevierville to Jefferson City Road—south side French Broad River (formerly principal access road south side, project 1002).				49,365.41
	Total Sevier County				425,030.95
-40	Jefferson County (27.4 miles):				
-4001	Dandridge Road				231,516.19
-4002	Kyker's Ferry Road				7,087.12
-4003	Seehorn Pond Road from U S 70 across Koontze Creek.				11,838.12
-4004	Oak Grove Road				43,467.01
-4005	Swann's Church Road				29,090.24
-4006	Oak Grove-Leadvale Road				171,594.43
-4011	Leadvale-Solomon Ferry Road				56,055.66
-4012	Leadvale-Bethear Road				7,366.90
-4013	McZion Church Road				24,480.68
-4015	White Pine-Nina Road				13,143.95
-4081	Bridge over French Broad River at Dandridge.				459,417.16
-4501	Roaring Springs-Dickey School Road.				59,801.02
-4502	Chestnut Hill-Dandridge Road at Muddy and Clear Creeks.				288,764.08
-4503	Chestnut Hill-Dandridge Road				31,487.84
-4504	Chestnut Hill-Dandridge Road at Chambers Branch.				16,140.62
-4505	Chambers Branch Road from Sandy Ridge east.				11,500.84
-4506	Tryon-Dandridge Road				227,857.60
-4507	Tryon-Reedtown Road				21,648.55
-4508	Muddy Hollow Road				56,776.98
-4509	Chestnut Hill-Dandridge Road				249,216.77
-4511	Sandy Ridge Branch Road				3,435.28
-4512	Muddy Creek Road, from Tryon to Dandridge Road south.				5,247.64
-4513	Chestnut Hill to Dandridge Road.				15,480.99
	Total Jefferson County				2,042,415.67
-50	Hamblen County (0.20 mile):				
-5001	Solomon Ferry to Beulah Chapel Road at Long Creek.				23,159.54
-5002	Solomon Ferry Road at west bank of Nolichucky River.				1,500.00
	Total Hamblen County				24,659.54
-60	Cocke County (5.05 miles):				
-6001	Holttown-Bybee Road				118,129.32
-6002	Clay Creek Road				28,368.84
-6003	Rankin-Bybee Road				8,650.28
-6004	Solomon Ferry-Point Pleasant Road.				17,847.06
-6005	Solomon Ferry Road at east bank of Nolichucky River.				1,500.00
-6081	Rankin Bridge across French Broad River.				38,699.77
-6501	Rankin-Newport Road				29,819.08
-6504	Rankin Bridge Approach				32,201.65
-6505	McNabb School Road				4,144.28
	Total Cocke County				279,360.28
	Municipal streets (0.3 mile):				
-70	Dandridge:				
-7001	Chestnut Hill to Dandridge Road in Dandridge.				39,372.17
-13	Tertiary roads:				
-1303	Sevier County (1 mile)				4,883.31
-1304	Jefferson County (8.03 miles)				70,575.57
-1306	Cocke County (6.48 miles)				27,432.22
	Total tertiary roads				102,891.10
	Total account No. 204				5,019,745.42

TABLE 44.—*Land costs and direct construction costs—details*—Continued

RELOCATING HIGHWAYS AND HIGHWAY BRIDGES—DETAIL BY COMPONENTS AS INDICATED

BRIDGE REMOVALS

Account	Land rights highway easements	Land privilege acquisition	Construction and maintenance division	Dam construction division	Contract work	Total
204-1204			$25,211.70			$25,211.70

STATE AND FEDERAL HIGHWAYS

Account	Land rights highway easements	Land privilege acquisition	Construction and maintenance division	Dam construction division	Contract work	Total
204-2000					$64,910.00	$64,910.00
-2002	$10,523.00	$3,015.36	$455,237.42			468,775.78
-2081	261.00	251.28	369,003.78	$600,440.75	277,729.45	1,247,686.26
-2082			50,924.98	248,506.99		299,431.97
	10,784.00	3,266.64	875,166.18	848,947.74	342,639.45	2,080,804.01

SEVIER COUNTY HIGHWAYS

Account	Land rights highway easements	Land privilege acquisition	Construction and maintenance division	Dam construction division	Contract work	Total
204-3002	$1,591.95	$2,261.52	$27,256.94			$31,110.41
-3081			114,012.23	$159,994.02		274,006.25
-3101			36,482.39	34,066.49		70,548.88
-3102	2,065.50	753.84	46,546.07			49,365.41
	3,657.45	3,015.36	224,297.63	194,060.51		425,030.95

JEFFERSON COUNTY HIGHWAYS

Account	Land rights highway easements	Land privilege acquisition	Construction and maintenance division	Dam construction division	Contract work	Total
204-4001	$3,725.00	$3,015.36	$224,775.83			$231,516.19
-4002	338.00	1,005.12	5,744.00			7,087.12
-4003	673.00	1,005.12	10,160.00			11,838.12
-4004	877.00	1.507.68	41,082.33			43,467.01
-4005	2,052.00	2,010.24	25,028.00			29,090.24
-4006	5.554.20	4,774.32	161,265.91			171,594.43
-4011	1,545.40	3,517.92	50,992.34			56,055.66
-4012	131.50	1,256.40	5,979.00			7,366.90
-4013	1,249.00	1,507.68	21,724.00			24,480.68
-4015			13,143.95			13,143.95
-4081			203,230.10		$256,187.06	459,417.16
-4501	1,085.00	1,507.68	57,208.34			59,801.02
-4502	3,163.50	3,266.04	128,204.89		154,129.05	288,764.08
-4503	142.00	753.84	30,592.00			31,487.84
-4504	212.50	1,005.12	14,923.00			16,140.62
-4505	519.00	753.84	10,228.00			11,500.84
-4506	3.455.60	3.517.92	130,791.72		90,092.36	227,857.60
-4507	716.75	2,512.80	18,419.00			21,648.55
-4508	765.00	2,261.52	53,750.46			56,776.98
-4509	2,225.80	3,769.20	102,335.77		140,886.00	249,216.77
-4511	184.00	251.28	3,000.00			3,435.28
-4512	235.00	753.84			4,258.80	5,247.64
-4513			15,480.99			15,480.99
	28,849.25	39,953.52	1,328,059.63		645,553.27	2,042,415.67

HAMBLEN COUNTY HIGHWAYS

Account	Land rights highway easements	Land privilege acquisition	Construction and maintenance division	Dam construction division	Contract work	Total
204-5001	$95.00	$502.56	$22,561.98			$23,159.54
-5002					$1,500.00	1,500.00
	95.00	502.56	22,561.98		1,500.00	24,659.54

TABLE 44.—*Land costs and direct construction costs—details*—Continued

RELOCATING HIGHWAYS AND HIGHWAY BRIDGES—DETAIL BY COMPONENTS AS INDICATED—Continued

COCKE COUNTY HIGHWAYS

Account	Land rights highway easements	Land privilege acquisition	Construction and maintenance division	Dam construction division	Contract work	Total
204-6001	$2,010.30	$2,764.08	$113,354.94			$118,129.32
-6002	130.00	753.84	27,485.00			28,368.84
-6003	200.00	251.28	8,199.00			8,650.28
-6004	97.50	502.56	17,247.00			17,847.06
-6005					$1,500.00	1,500.00
-6081			38,699.77			38,699.77
-6501	354.00	2,764.08	26,701.00			29,819.08
-6504	22.50	251.28	31,927.87			32,201.65
-6505	160.00	251.28	3,733.00			4,144.28
	2,974.30	7,538.40	267,347.58		1,500.00	279,360.28

MUNICIPAL STREETS

Account	Land rights highway easements	Land privilege acquisition	Construction and maintenance division	Dam construction division	Contract work	Total
204-7001	$1,990.00	$1,256.40	$36,125.77			$39,372.17

TERTIARY ROADS

Account	Land rights highway easements	Land privilege acquisition	Construction and maintenance division	Dam construction division	Contract work	Total
204-1303	$214.00	$502.56	$4,166.75			$4,883.31
-1304	1,005.95	4,020.48	65,549.14			70,575.57
-1306	1,252.40	3,015.36	23,164.46			27,432.22
	2,472.35	7,538.40	92,880.35			102,891.10

SUMMARY

Account	Land rights highway easements	Land privilege acquisition	Construction and maintenance division	Dam construction division	Contract work	Total
Total Account 204	50,822.35	63,071.28	2,871,650.82	$1,043,008.25	$991,192.72	5,019,745.42

LAND AND LAND RIGHTS—Continued

Account	Description	Quantity	Unit	Rate	Amount
205	Relocating railways and railway bridges:				
-2	Southern Ry. system relocation:				
-2	Land for transportation purposes:				
	Purchase price of land easement				$457.80
	Land acquisition expense				2,261.52
-3	Grading				744,616.96
-6	Bridges, trestles, and culverts:				
	Bridge at French Broad River crossing				292,172.38
	Other minor structures				88,372.73
-8	Ties				25,563.31
-11	Ballast				133,623.74
-12	Track laying and surfacing				190,701.86
-13	Fences, snow sheds, and signs				4,819.04
-16	Station and office buildings				937.27
-17	Roadway buildings				11,889.26
-18	Water stations				123,485.98
-19	Fuel stations				97,423.12
-26	Telegraph and telephone lines				1,015.32
-27	Signals and interlockers				47,287.74
-39	Public improvements				26,126.49
	Total account No. 205				1,790,754.52

TABLE 44.—*Land costs and direct construction costs—details*—Continued

LAND AND LAND RIGHTS—Continued

Account	Description	Quantity	Unit	Rate	Amount
207	Relocating other structures and improvements:				
-0	Relocating utilities:				
-00	Power lines:				
	Land easements				$150.00
	Land acquisition				753.84
	Line construction				89,147.85
-01	Telephone, telegraph, and signal control lines.				63,198.28
	Total Account No. 207-0				153,249.97
-1	Relocating cemeteries	2,449	Grave	$19.03	46,594.49
-3	Relocating families	525	Family	113.11	59,382.06
-4	Sewer system, Dandridge, Tenn				3,158.25
-5	Water system, Dandridge, Tenn				7,895.05
-7	Streets, Dandridge, Tenn				33,181.83
-8	Protection of French Broad Baptist Church.				36,232.40
	Total account No. 207				339,694.05
	Total land and land rights				13,945,346.90

STRUCTURES AND IMPROVEMENTS

DIRECT CONSTRUCTION COSTS

Account	Description	Quantity	Unit	Rate	Amount
212	General yard improvements:				
-0	Grading and landscaping:				
-00	General grading				$60,698.03
-01	Landscaping				25,168.38
-02	Riprap slopes				20,869.41
	Total, account No. 212-0				106,735.82
-1	Roads, sidewalks, bridges, and trestles:				
-10	Roadways, drives, and courts				78,699.78
-11	Sidewalks				1,411.82
-12	Curbs				18,259.50
	Total, account No. 212-1				98,371.10
-2	Retaining walls, fences, gates, and railings:				
-21	Fences, gates, and railings				8,886.96
-4	Water treating, pumping, and storage equipment:				
-40	Water-treating plant				14,429.53
-42	Storing equipment				13,537.22
-43	Intake structure and supply lines				6,646.49
	Total, account No. 212-4				34,613.24
-5	Water distribution lines				7,095.90
-6	[illegible]tem				27,069.63
-9	[illegible]				
-90	[illegible]d hardware				1,709.77
-92	[illegible] and lighting cabinets				14.88
-93	Grounding system				39.90
-95	Conduit work				21.06
-96	Conductor				2,351.42
-98	Transformers				533.20
-99	Lighting standards, fixtures, and lamps	32	Fixture	$32.09	1,026.81
	Total, account No. 212-9				5,697.04
	Total, account No. 212				288,469.69

TABLE 44.—*Land costs and direct construction costs—details*—Continued

STRUCTURES AND IMPROVEMENTS—Continued

DIRECT CONSTRUCTION COSTS—Continued

Account	Description	Quantity	Unit	Rate	Amount
213	Powerhouse:				
-1	Diversion and care of water:				
-11	[illegible]				$31,438.14
-13	[illegible]				204,506.11
	Total account No. 213-1				235,944.25
-2	Excavation and backfill:				
-22	Earth excavation	6,762	Cubic yard	$1.23	8,314.37
-23	Rock excavation	25,972	do	4.79	124,291.76
	Total account No. 213-2				132,606.13
-3	[illegible]				
-30	[illegible]	9,816	Linear foot	0.79	7,774.71
-37	[illegible]	3,311	Cubic foot	2.78	9,197.51
-38	Foundation drains				1,920.51
	Total account No. 213-3				18,892.73
-4	Concrete:				
-40	Subscructure concrete:				
-400	Concreting	35,692	Cubic yard	11.10	396,085.86
-401	Formwork	148,876	Square foot	1.98	294,590.38
-402	Reinforcing	869.63	Ton	120.73	104,992.83
	Total powerhouse substructure concrete.	35,692	Cubic yard	22.29	795,669.07
-41	*Superstructure concrete:*				
-410	Concreting	5,863	Cubic yard	16.23	95,189.41
-411	Formwork	81,166	Square foot	2.14	174,022.03
-412	Reinforcing	422.77	Ton	124.60	52,676.27
	Total powerhouse superstructure concrete.	5,863	Cubic yard	54.90	321,887.71
	Total account No. 213-4				1,117,556.78
-5	Joints, stops, waterproofing, and drains:				
-50	Expansion joints and water stops, all types.				15,463.91
-6	Superstructure:				
-61	Interior masonry:				
-610	Structural tile partitions	25,085	Square foot	0.64	16,148.28
-611	Brick partitions	6,318	do	2.49	15,758.19
-616	Soundproofing	1,687	do	.39	663.71
-62	Steel and other metal work:				
-620	Structural steel	594.86	Ton	198.02	117,796.59
-621	Miscellaneous steel and iron	82.52	do	704.08	58,100.32
-622	Generator covers	69.40	do	411.25	28,540.71
-63	Carpentry work:				
-632	Kalamein or metal doors				31,834.91
-633	Window sash—steel				5,996.89
-634	Temporary floor—unit 2				14,593.19
-64	Cement work	25,245	Square foot	1.07	27,136.28
-65	Marble, terrazzo, tile:				
-650	Marble work	141.2	do	4.01	566.32
-651	Tile work:				
-6510	Wall tile	4,462	do	2.75	12,277.44
-6511	Floor tile	4,408	do	0.64	2,828.03
-652	Terrazzo	4,024	do	0.89	3,569.10
-653	Linoleum	4,580	do	0.38	1,759.35
-66	Roofing and sheet metal work	15,383	do	1.76	27,129.46
-67	Plaster work				21,806.36
-68	Painting and glazing:				
-680	Painting				12,773.40
-681	Glass and glazing	1,234	Square foot	1.07	1,322.90
-69	Protection and clean up				6,295.44
	Total account No. 213-6				406,896.87

TABLE 44.—*Land costs and direct construction costs—details*—Continued

STRUCTURES AND IMPROVEMENTS—Continued

DIRECT CONSTRUCTION COSTS—Continued

Account	Description	Quantity	Unit	Rate	Amount
	Powerhouse—Continued				
-8	Service work:				
-80	Plumbing and drainage				$49,856.13
-82	Heating, electric				5,663.44
-83	Air conditioning and ventilating:				
-830	Ducts				32,446.12
-831	Equipment and controls				34,508.94
-89	Lighting:				
-890	Control panels and cabinets				2,542.36
-891	Conduit work	26,425	Pound	$0.73	19,383.26
-892	Wiring				4,966.29
-895	Fixtures, switches, and receptacles	706	Outlet	12.08	8,526.52
	Total account No. 213-8				157,893.06
	Total account No. 213				2,085,253.73
215	Intake structure				
-1	Diversion and care of water:				
-11	Earth dike cofferdam				6,287.63
-13	Timber crib cofferdam				40,901.22
	Total account No. 215-1				47,188.85
-2	Excavation and backfill:				
-22	Earth excavation	1,294	Cubic yard	1.23	1,591.07
-23	Rock excavation	2,090	do	4.79	10,001.91
	Total account No. 215-2				11,592.98
-4	Concrete:				
-42	Concrete trash-rack structure:				
-420	Concreting	949	Cubic yard	16.56	15,719.33
-421	Formwork	17,471	Square feet	2.41	42,019.06
-422	Reinforcing steel	39.47	Ton	204.91	8,087.81
	Total account No. 215-4				65,826.20
-6	Gates and appurtenances:				
-62	Intake gates:				
-620	Gate frames and guides	83.56	Ton	708.94	59,239.19
-621	Gates and seals	168.36	do	824.70	138,846.84
-623	Screens, supports, and trash racks				34,731.54
-625	Gate-handling equipment				89,379.76
	Total account No. 215-6				322,197.33
	Total account No. 215				446,805.36
216	MISCELLANEOUS BUILDINGS				
-1	Guard shelter				224.99
-2	Service building				4,921.06
	Total account No. 216				5,146.05
	Total structures and improvements				2,825,674.83

TABLE 44.—*Land costs and direct construction costs—details*—Continued

RESERVOIRS, DAMS, AND WATERWAYS

DIRECT CONSTRUCTION COSTS

Account	Description	Quantity	Unit	Rate	Amount
220	[illegible]				
-0	[illegible]	4,827.40	Acre	$103.20	$498,193.59
-1	[illegible]ls				3,021.32
-2	[illegible] flotage				954.78
-8	Rim treatment:				
-80	Drilling	28,268	Linear foot	4.20	118,694.02
-81	Pressure grouting	217,249	Cubic foot	1.13	245,021.25
	Total account No. 220-8				363,715.27
-9	[illegible]				
-90	[illegible]				13,114.42
-91	[illegible]	11,671.1	Cubic yard	4.18	48,786.60
	Total account No. 220-9				61,901.02
	Total account No. 220				927,785.98
221	Concrete dam and spillway:				
-1	Diversion and care of water:				
-11	Earth dike cofferdam				324,860.64
-13	Timber crib cofferdam:				
-131	Stage No. 1				1,431,537.83
-132	Stage No. 2				431,012.79
-133	Temporary penstock bulkheads				12,467.60
-16	Water control during construction				759.74
-17	Control and disposal of miscellaneous flotage.				1,199.92
-19	Final closure				15,329.54
	Total account No. 221-1				2,217,168.06
-2	Excavation and backfill:				
-22	Earth excavation	137,765	Cubic yard	1.23	169,392.07
-23	Rock excavation	277,676	do	4.79	1,328,847.94
-24	Backfill	92,160	do	.78	71,837.43
	Total account No. 221-2				1,570,077.44
-3	Foundation preparation and treatment:				
-30	Drilling drain and grout holes	130,806	Linear foot	2.29	299,879.40
-31	[illegible]	14,298	do	0.90	12,827.08
-35	[illegible]	3,374	Cubic yard	57.48	193,945.28
-37	Pressure grouting	91,360	Cubic foot	2.78	253,785.46
-38	Foundation drains	10,597	Linear foot	2.12	22,481.28
	Total account No. 221-3				782,918.50
-4	Concrete:				
-40	Mass concrete:				
-400	Concreting	451,829	Cubic yard	9.15	4,132,469.41
-401	Formwork	865,728	Square foot	1.19	1,033,881.54
-402	Reinforcing	1,613.75	Ton	127.11	205,116.61
	Total mass concrete	451,829	Cubic yard	11.89	5,371,467.56
-42	Spillway pier and training wall concrete:				
-420	Concreting	8,256	do	11.30	93,326.32
-421	Formwork	55,297	Square foot	1.20	66,133.93
-422	Reinforcing	171.22	Ton	130.41	22,329.32
	[illegible] and train-	8,256	Cubic yard	22.02	181,789.57
-44	Apron concrete:				
-440	Concreting	35,505	do	11.38	404,074.39
-441	Formwork	65,261	Square foot	1.28	83,290.47
-442	Reinforcing	294.73	Ton	125.12	36,875.59
	Total apron concrete	35,505	Cubic yard	14.77	524,240.45
	Total account No. 221-4				6,077,497.58
-5	Joints, stops, waterproofing, and drains:				
-50	Expansion joints and water stops—all types.				51,108.72
-58	Drains, formed or porous tile				38,213.79
	Total account No. 221-5				89,322.51

TABLE 44.—*Land costs and direct construction costs—details*—Continued

RESERVOIRS, DAMS, AND WATERWAYS—Continued

DIRECT CONSTSUCTION COSTS—Continued

Account	Description	Quantity	Unit	Rate	Amount
221	Concrete dam and spillway—Continued				
-6	[illegible]				
-60	[illegible]				
-600	[illegible] guides	700.25	Ton	$591.21	$413,999.30
-602	Operating equipment				30,370.73
-603	Outlet screens and screen supports.	49.78	Ton	228.21	11,360.30
-604	Stop log guides and bulkheads	55.70	do	436.24	24,298.38
-61	Crest gates:				
-610	Gate frames and guides	264.51	do	277.45	73,388.54
-611	Gates and seals				273,444.14
-612	Operating equipment				159,575.25
	Total account No. 221-6				986,436.64
-7	Auxiliary structures and equipment:				
-71	Elevator:				
-710	Equipment				19,530.95
-714	Concrete superstructure	82	Cubic yard	108.10	8,863.92
-715	Roofing and flashing				63.60
-716	Interior finish				1,877.85
-717	Carpentry and metalwork				8,012.45
-72	Spillway bridge:				
-720	Structural steel	196.87	Ton	240.75	47,396.04
-724	Concrete deck	156.00	Cubic yard	22.33	3,483.66
-73	Sluiceway conduit liners	202.40	Ton	372.73	75,441.35
-74	Miscellaneous steel and iron				22,999.39
-75	Handrailing				13,536.88
-76	Piping				5,771.40
-77	Pressure or other measuring devices:				
-771	Isolated gaging stations and devices.				1,189.25
-772	Other pressure and gaging devices.				701.35
	Total account No. 221-7				208,868.09
-9	Electric work:				
-91	Switchgear				464.57
-92	Switchboards				578.34
-93	Protective equipment				7,486.27
-95	Conduit work				27,111.35
-96	Wiring, power and control:				
-960	Wire and cable				8,526.67
-967	Power plugs and receptacles				174.19
-98	Transformers				3,158.72
-99	Lighting:				
-990	Cabinets				1,446.08
-991	Conduit				6,225.16
-992	Wiring				2,714.48
-993	Fixtures	269	Outlet	21.83	5,871.40
	Total account No. 221-9				63,757.23
	Total account No. 221				11,996,046.05
222	Auxiliary dams:				
-1	Saddle dams 1, 3, 4, 5, 6, 8, 9, and 10:				
-11	Diversion and care of water				1,541.21
-12	Excavation and backfill	57,823	Cubic yard	.74	42,556.45
-13	Foundation preparation and treatment:				
-130	Drilling grout holes	14,866	Linear foot	2.28	33,856.72
-137	Pressure grouting	41,127	Cubic foot	1.95	80,278.93
-15	Permanent drainage:				
-150	Trenching and backfill				79,859.64
-151	Tile and concrete drains, manholes, and catch basins.				21,416.57
-152	Stone and gravel backfill	1,523	Ton	2.65	4,030.82
-155	Pervious drain blanket	19,380	do	1.62	31,370.25
-17	Earth fill:				
-170	Preparation of borrow pits				34,953.59
-171	Loading and hauling	531,840	Cubic yard	.32	168,657.32
-172	Spreading and compacting	531,840	do	.13	68,194.00

TABLE 44.—*Land costs and direct construction costs—details*—Continued

RESERVOIRS, DAMS, AND WATERWAYS—Continued

DIRECT CONSTRUCTION COSTS—Continued

Account	Description	Quantity	Unit	Rate	Amount
222	Auxiliary dams—Continued				
	Saddle dams 1, 3, 4, 5, 6, 8, 9, and 10—Continued				
-18	Slope protection:				
-180	Gravel blanket	28, 611	Ton	$1. 64	$46, 930. 25
-181	Riprap	53, 398	Cubic yard	3. 07	163, 728. 01
-183	Seeding and sodding				8, 944. 23
-184	Gutters, curbs, and walls	474	Cubic yard	42. 15	19, 980. 28
	Total account No. 222-1				806, 348. 27
-2	Dandridge dike, diversion conduits, and pumping station:				
-20	Main dike:				
-202	Excavation	41, 976	Cubic yard	3. 09	129, 710. 17
-203	Foundation preparation and treatment:				
-2030	Drilling	15, 697	Lineal foot	5. 21	81, 789. 69
-2038	Grouting	151, 880	Cubic foot	. 96	146, 052. 56
-204	Cut-off wall	2, 499	Cubic yard	10. 93	27, 315. 26
-205	Permanent drainage				26, 198. 75
-207	Rolled fill	161, 150	Cubic yard	. 63	102, 307. 65
-208	Slope protection:				
-2080	Gravel blanket	2, 950	Ton	7. 34	21, 667. 25
-2081	Riprap	13, 889	Cubic yard	4. 70	65, 248. 00
-2083	Seeding and sodding				7, 982. 54
-2085	Sidewalks and stairs				2, 365. 16
	Total main dike				610, 637. 03
-21	Parking area:				
-210	Grading				4, 176. 04
-211	Surfacing				2, 108. 58
-212	Drainage system				937. 85
-213	Guardrails and curbs				2, 933. 56
	Total parking area				10, 156. 03
-22	Diversion conduits:				
-220	North Creek diversion conduit:				
-2200	Diversion dike				22, 174. 14
-2201	Concrete pipe conduit				162, 854. 41
	Total North Creek diversion conduit.				185, 028. 55
-221	West Creek diversion conduit:				
-2210	Diversion dike				13, 404. 94
-2211	Concrete pipe conduit				63, 923. 31
	Total West Creek diversion conduit.				77, 328. 25
	Total diversion conduits				262, 356. 80
-23	Pumping station, and collection and discharge lines:				
-230	Pumping station:				
-2300	Excavation and backfill				9, 532. 18
-2301	Structure				22, 390. 87
-2302	Equipment and piping				20, 535. 59
-2303	Preliminary operation				1, 701. 93
-2304	Fence				330. 50
	Total pumping station				54, 491. 07
-231	Sewerage discharge lines				1, 297. 45
-232	Storm water lines:				
-2320	Collection lines				6, 426. 74
-2321	Discharge line				21, 273. 43
	Total storm water lines				27, 700. 17
	Total pumping station, and collection and discharge lines.				83, 488. 69
	Total account No. 222-2				966, 638. 55
	Total account No. 222				1, 772, 986. 82

Table 44.—*Land costs and direct construction costs—details*—Continued

RESERVOIRS, DAMS, AND WATERWAYS—Continued

Direct Construction Costs—Continued

Account	Description	Quantity	Unit	Rate	Amount
226	Water conductors:				
-3	Penstock:				
-30	Penstock pipe	331.40	Ton	$365.55	$121,141.48
-33	Penstock vent and bypass piping				11,311.68
	Total account No. 226-3				132,453.16
-8	Tailrace:				
-81	Diversion and care of water				424,699.62
-82	Excavation:				
-822	Earth	8,751	Cubic yard	1.23	10,759.99
-823	Rock	17,929	do	4.79	85,801.13
-83	Foundation preparation and treatment.				1,846.15
-84	Concrete work	4,132	Cubic yard	16.53	68,287.50
-85	Water seals and drains				523.84
	Total account No. 226-8				591,918.23
	Total account No. 226				724,371.39
	Total reservoirs, dams, and waterways.				15,421,190.24

WATER WHEELS, TURBINES, AND GENERATORS

Direct Construction Costs

230	Foundations and miscellaneous steel and iron:				
-0	Miscellaneous steel and iron	4.87	Ton	$491.53	$2,393.74
-3	Draft tube pier nose castings	2.95	do	332.11	979.72
	Total account No. 230				3,373.46
231	Turbines, including scroll case, speed ring, and draft tube liners (vertical shaft, Francis type, rated at 41,500 h.p. at 100 foot net head).	2	Each	373,086.55	746,173.09
	Total account No. 231				746,173.09
232	Auxiliary equipment for turbines:				
-0	Governors	2	Each	38,012.44	76,024.88
-2	Scroll case filling and drainage system				16,151.68
-9	Auxiliary equipment not otherwise classified:				
-90	Turbine vent piping				507.38
-91	Head and tailwater gage piping				2,519.33
-92	Turbine piezometer piping system				1,901.57
	Total account No. 232-9				4,928.28
	Total account No. 232				97,104.84
233	Draft tube gates:				
-0	Gate frames and guides	30.38	Ton	904.20	27,469.61
-1	Gates and seals	32.20	do	469.80	15,127.42
-2	Gate handling chains and dogging devices.	4.73	do	515.80	2,439.75
-5	Bulkheads, timber and steel	19.75	do	405.61	8,010.78
	Total, account No. 233				53,047.56
235	Generators (33,333 kilovolt-amperes at 0.9 pf, 13,800-volt, 94.7 r. p. m).	2	Each	431,120.64	862,241.27
	Total, account No. 235				862,241.27

TABLE 44.—*Land costs and direct construction costs—details*—Continued

WATER WHEELS, TURBINES, AND GENERATORS—Continued

DIRECT CONSTRUCTION COSTS—Continued

Account	Description	Quantity	Unit	Rate	Amount
236	Auxiliary equipment for generator:				
-0	Excitation panels, switches, and rheostats.	2	Each	$3,850.98	$7,701.95
-1	Generator cooling water system				8,057.42
-9	Fire extinguishing equipment				7,289.75
	Total, account No. 236				23,049.12
239	Miscellaneous equipment for turbine and generator:				
-0	Lubrication and governor oil storage and purifying equipment.				18,548.45
	Total, account No. 239				18,548.45
	Total, water wheels, turbines, and generators.				1,803,537.79

ACCESSORY ELECTRIC EQUIPMENT

DIRECT CONSTRUCTION COSTS

Account	Description	Quantity	Unit	Rate	Amount
241	Switch gear:				
-1	Assembled switch gear:				
-11	Housing, equipment, and bus work (13.8-kilovolt).				$23,069.93
-14	Generator neutral switch gear				7,000.59
	Total account No. 241-1				30,070.52
-2	Circuit brakers (15-kilovolt)	2	Each	$10,340.26	20,680.53
	Total account No. 241				50,751.05
242	Switchboards:				
-1	Main control boards and terminal cabinets.				62,706.33
-3	440-volt auxiliary power boards				40,370.06
-4	220-volt auxiliary power boards for heating and lighting.				5,832.63
-5	Battery boards				7,508.19
-6	Signal system boards				10,956.03
-7	Power distribution cabinets				1,994.31
	Total account No. 242				129,367.60
243	Protective equipment				
-2	Grounding system				7,512.57
-5	Fire extinguishing equipment				5,105.72
	Total account No. 243				12,618.29
244	Electrical structures:				
-4	Cable trays				8,467.27
	Total account No. 244				8,467.27
245	Conduit work:				
-1	Metallic conduit	115,184	Pound	$0.40	45,734.82
-2	Nonmetallic conduit	15,289	do	0.31	4,798.11
-3	Conduit boxes				2,480.09
-4	Concrete envelopes	73.0	Cubic yard	29.38	2,144.91
	Total account No. 245				55,157.93
246	Power and control wiring:				
-1	Control, auxiliary power, and excitation wiring, 4000 volts and under.				19,450.77
-2	Main power cables, 15,000 volts				8,551.53
-7	Plugs and receptacles				1,406.29
	Total account No. 246				29,408.59

TABLE 44.—*Land costs and direct construction costs—details*—Continued

ACCESSORY ELECTRIC EQUIPMENT—Continued

DIRECT CONSTRUCTION COSTS—Continued

Account	Description	Quantity	Unit	Rate	Amount
249	Station service equipment:				
-1	Transformers				
-11	Auxiliary power transformers (2 at 1,000-kilovolt-ampere; 1 at 600-kilovolt-ampere; 3 at 3-kilovolt-ampere.				$14,585.33
-12	Lighting and heating transformers (2 at 100-kilovolt-ampere; 2 at 2-kilovolt-ampere; 14 at 350-volt-ampere).				2,187.36
	Total account No. 249-1				16,772.69
-2	Batteries, charging equipment, and other motor generator sets.				12,128.51
-6	Insulating oil storage and treating equipment:				
-60	Piping				3,592.39
-61	Tanks				3,737.26
-62	Oil-treating equipment				6,761.64
-63	Oil in storage				1,129.32
	Total account No. 249-6				15,220.61
-9	Equipment not otherwise classified:				
-92	Auxiliary generator (200-kilo-volt-ampere, 480-volt).				15,504.18
	Total account No. 249				59,625.99
	Total accessory electric equipment				345,369.72

MISCELLANEOUS POWER PLANT EQUIPMENT

DIRECT CONSTRUCTION COSTS

Account	Description	Quantity	Unit	Rate	Amount
252	Station maintenance equipment				$8,955.25
	Total account No. 252				8,955.25
255	Cranes and hoisting equipment:				
-1	225-ton powerhouse crane:				
-10	Crane	415.94	Ton	$658.40	273,853.20
-11	Crane track	21.03	do	209.36	4,402.93
	Total account No. 255-1				278,256.13
-2	5-ton service bay crane				2,212.83
	Total account No. 255				280,468.96
256	Compressed air and vacuum cleaning equipment:				
-1	Air compressors, tanks, and piping				9,106.33
	Total account No. 256				9,106.33
258	Station service water equipment				5,270.71
	Total account No. 258				5,270.71
259	Other miscellaneous equipment:				
-0	Communication equipment				17,735.89
-1	Fire-extinguishing equipment				1,187.59
-2	Furniture and fixtures				3,018.67
-3	Lockers, shelves, and cabinets				5,004.87
-5	Miscellaneous instruments				1,103.74
	Total account No. 259				28,050.76
	Total miscellaneous power plant equipment.				331,852.01

TABLE 44.—*Land costs and direct construction costs—details*—Continued

HYDRAULIC MULTIPLE PURPOSE PLANT—Concluded

VILLAGE AND RESERVOIR FACILITIES

DIRECT CONSTRUCTION COSTS

Account	Description	Quantity	Unit	Rate	Amount
271	Reservoir operation facilities:				
-1	Malaria-control bases:				
-11	Base No. 1 at Oak Grove, Tenn				$2,966.31
-12	Base No 2 at Shady Grove, Tenn				3,084.66
	Total account No. 271-1				6,050.97
-3	Isolated structures				724.86
-9	Portable malaria-control equipment				13,217.94
	Total account No. 271				19,993.77
	Total village and reservoir facilities				19,993.77

TRANSMISSION PLANT

STRUCTURES AND IMPROVEMENTS

DIRECT CONSTRUCTION COSTS

Account	Description	Quantity	Unit	Rate	Amount
422	General yard improvements:				
-0	Grading and landscaping:				
-00	Grading:				
-002	Excavation	11,322	Cubic yard	$1.03	$11,680.46
-003	Fill and backfill				128,267.82
-01	Landscaping and surfacing				15,847.56
	Total account No. 422-0				155,795.84
-2	Retaining walls, fences, gates, and railings:				
-21	Fences, gates, and railings				3,101.40
-8	Drainage				10,329.53
	Total account No. 422				169,226.77
424	Outdoor substation structures:				
-1	Foundations (for structures and equipment):				
-10	Piling	67.80	Ton	170.92	11,588.33
-11	Concrete	588	Cubic yard	57.99	34,096.32
	Total account No. 424-1				45,684.65
-3	Superstructure (structural steel)	88.23	Ton	246.64	21,761.39
-9	Lighting:				
-90	Cabinets				963.83
-91	Conduit	5,725	Pound	.31	1,754.05
-92	Wiring				829.77
-93	Fixtures, switches, and receptacles				1,202.11
	Total account No. 424-9				4,749.76
	Total account No. 424				72,195.80
	Total structures and improvements.				241,422.57

Table 44.—*Land costs and direct construction costs—details*—Continued

TRANSMISSION PLANT—Continued

STATION EQUIPMENT

Direct Construction Costs

Account	Description	Quantity	Unit	Rate	Amount
431	Switchgear:				
-1	Circuit breakers:				
-14	161-kilovolt breakers	3	Each	$29,906.33	$89,719.00
-2	Disconnecting switches:				
-21	15-kilovolt fuse disconnecting switches (manual).				273.75
-24	161-kilovolt disconnecting switches				21,508.04
	Total account No. 431-2				21,781.79
-3	Instrument transformers				413.74
	Total account No. 431				111,914.53
432	Switchboards:				
-7	Power distribution cabinets				519.29
	Total account No. 432				519.29
433	Protective equipment:				
-1	Lighting arresters and gaps				4,305.76
-2	Grounding system				7,988.52
-4	Resistors and reactors				3,850.60
	Total account No. 433				16,144.88
435	Conduit work:				
-1	Metallic conduit	22,252	Pound	.29	6,552.26
-2	Nonmetallic conduit	27,700	do	.25	6,982.59
-3	Conduit boxes				467.04
-4	Concrete envelopes	485	Cubic yard	29.23	14,176.92
-6	Manholes and covers				5,591.29
	Total account No. 435				33,770.10
436	Power and control wiring:				
-1	Control, auxiliary power, and excitation wiring—4,000-volt and under.				6,593.54
-2	Main power cables, 15,000-volt				16,619.54
-3	Special cable				954.48
-4	Bare conductors				8,790.70
-5	Insulators and hardware				7,620.45
-7	Plugs and receptacles (except lighting)				76.01
	Total account No. 436				40,654.72
438	Main conversion equipment:				
-1	Main step-up power transformers (1-phase, with forced draft equipment, 2-winding, 161–13.2-kilovolt, 20,000-kilovolt-ampere self-cooled, 26,667-kilovolt-ampere forced air cooled).	3	Each	44,288.29	132,864.88
	Total account No. 438				132,864.88
439	Station service equipment:				
-1	Station service transformers:				
-11	Lighting transformers				343.16
-4	Transformer and breaker handling equipment:				
-41	Tracks				5,026.86
-42	Transformer car				3,559.25
	Total account No. 439-4				8,586.11
-6	Insulating oil system:				
-61	Piping				4,388.44
-9	Equipment, not otherwise classified:				
-95	Fire protective equipment				2,262.57
	Total account No. 439				15,580.28
	Total station equipment				351,448.68

TABLE 44.—*Land costs and direct construction costs—details*—Continued

GENERAL PLANT

COMMUNICATION FACILITIES

DIRECT CONSTRUCTION COSTS

Account	Description	Quantity	Unit	Rate	Amount
378	Communication equipment:				
-1	Communication lines				5,698.89
-4	Exchange and station equipment:				
-42	Station installations				11,573.65
-9	General service equipment:				
-94	Coupling capacitors, line traps, and tuning units.				18,243.04
	Total account No. 378				35,515.58
	Total general plant communication facilities.				35,515.58

TABLE 45.—*Indirect construction costs*

Superintendence, accounting, and timekeeping: salaries and expenses of the superintendent of construction and his immediate assistants in the field and office; salaries and expenses in connection with field accounting, timekeeping and cost engineering; similar charges from other divisions; and cost of training personnel	$489,839.47
Travel and subsistence: personal transportation, per diem allowance, and miscellaneous expense of supervisory personnel when in official travel status	23,683.44
Office supplies and expense: miscellaneous expense of the field offices including stationery and other office supplies; blueprints; photostats; telephone; telegraph; and maintenance of office space, including heat, light and water	142,535.59
Construction plant studies and design: preliminary investigations, studies, and estimates of construction schedules and construction plant layout, including cofferdams, and construction plant and equipment	52,646.64
Camp operation: camp construction costs inclusive of camp equipment, and expense of operation of cafeteria, commissaries and dormitories	400,413.06
Temporary access railroad: cost of construction, maintenance, and removal of an access railroad from Ewing, Tenn., to the dam site, including the loss on the sale of railroad right-of-way	560,817.31
Temporary access road: construction and maintenance costs for north and south access roads to the dam site	112,786.59
Safety activities: labor and expense for assistance given the safety engineer and cost of safety signs, posters, and bulletins	3,642.09
Police and guide service: police and guide service maintained for benefit of the project, together with minor expense for accomodation of guests on official visits; injuries to nonemployees; and private land use restrictions in the immediate vicinity of the dam	133,332.30
Cost of obtaining equipment from other TVA construction projects: the similarity of equipment design for the projects of Cherokee and Douglas permitted equipment originally ordered and delivered for Cherokee but not yet placed in service at that project, to be transferred to Douglas, when such action would result in an earlier operation date than would have been otherwise possible for Douglas project. A small amount of equipment was transferred also from other projects under construction. Costs shown here include initial installation and handling costs at the original projects and secondary transportation to Douglas	63,019.16

TABLE 45.—*Indirect construction costs*—Continued

Liquidated damages and other credits: liquidated damages collected from contractors or vendors, and credits for percentages added to bills against vendors, contractors, and others for overhead charges on services rendered by the TVA	[1] $39, 089. 68
Total indirect construction costs	1, 946, 625. 97

TABLE 46.—*Distributive general expense*

Design and construction engineering costs

Engineering—Field and office: salaries and expenses of field, executive supervisory, and office engineers; concrete technicians, inspectors and assistants; services of consultants; foundation borings and explorations; soil technology; and engineering for vertical and horizontal controls	$723, 204. 93
Dam site and regional geology: general examinations, studies, and reports on proposed dam sites and adjacent areas; and studies of the effect of dam construction on sinks, wells, and springs in the reservoir area	11, 542. 66
Design by TVA: design of dam, powerhouse, switchyard, and other related structures; landscape treatment in immediate vicinity of dam; preparation of specifications; design for highway, bridge, and railroad relocations; and design for miscellaneous backwater protection	577, 988. 99
Total, design and construction engineering costs	1, 312, 736. 58

Executive and administrative costs

Divisional and general administrative costs: proration of the total divisional and general administration of the Tennessee Valley Authority applicable to the Douglas project	1, 310, 324. 89
Total, executive and administrative costs	1, 310, 324. 89

Other general costs

Maps and surveys: surveys and investigations for basic horizontal and vertical controls in the reservoir area; dam site and reservoir topography; and other general surveys and mapping	51, 271. 14
Hydraulic data: readjustment to the existing stream gaging facilities necessitated by filling of the reservoir; observation of test holes, ground water wells, springs, and runs in vicinity of dam for determining possible leakage; and preparation of reports on reservoir and tributary data for determining conditions before and after filling the reservoir	17, 935. 98
General project investigations: general studies and investigations for location of dam, project design, and regional economics; flood control studies; and power generation studies	24, 975. 38
Construction medical service: operation of medical center and portable dressing stations for care of employees claiming service-connected injuries; employment physical examinations and treatment of minor illness occurring to employees while on duty; and services of safety engineer	178, 105. 41
Personnel and training department: services of the personnel representatives, interviewers, and clerical staff engaged as field representatives in recruitment, placement, promotion, classification, and service rating; services of a training staff through overtime payments to TVA employees teaching job and in-service training classes; operation of theater; and recreational programs	55, 507. 19
Office service: messenger, files, mail, and courier service	18, 924. 16
Final project report: editing of individual reports on the planning, design, construction, cost, and initial operation of the project into one comprehensive report, including preparation of any needed additional drawings or illustrations, and printing and binding	7, 567. 66
Total other general costs	354, 286. 92

[1] Denotes credit.

TABLE 47.—*Details of certain indirect construction costs and distributive general expense*

Item	Project field offices			Central accounting office	Total
	Construction and maintenance	Reservoir clearance	Dam construction		
INDIRECT CONSTRUCTION COSTS					
Superintendence	$9,509.95	$16,492.07	$66,828.95	----	
Accounting, cost engineering, and timekeeping	103,801.07	17,041.74	268,657.21	----	
Training personnel	----	----	600.69	----	$489,839.47
Miscellaneous charges from other divisions	5,174.10	----	1,733.69	----	
Travel and subsistence	1,087.79	7,813.37	17,782.28	----	26,683.44
Office supplies and expense	21,763.92	3,351.79	117,419.88	----	142,535.59
Construction plant studies and design	----	----	----	$52,646.64	52,646.64
Camp construction	----	----	273,908.73	4,262.67	400,413.06
Camp operation	----	----	[1] 122,241.66	----	
Temporary access railroad	----	----	511,891.97	48,925.34	560,817.31
Temporary access road	----	----	112,786.59	----	112,786.59
Safety activities	----	2,936.48	705.61	----	3,642.09
Public liabilities	----	----	1,055.56	----	
Public facilities and accommodation of guests	----	----	3,527.84	----	
Police and guide service	----	----	[1] 128,348.90	----	133,332.30
Private land use restrictions in vicinity of dam	----	----	----	400.00	
Cost of obtaining equipment from other TVA construction projects	----	----	63,019.16	----	63,019.16
Liquidated damages and distribution of other credits	[2] 27,907.16	[2] 53.91	[2] 11,128.61	----	39,089.86
Total	113,429.67	47,581.54	1,679,380.11	106,234.65	1,946,625.97
DISTRIBUTIVE GENERAL EXPENSE					
Design and construction engineering cost:					
Engineering, field and office	11,498.26	----	601,677.73	106,843.95	723,204.93
Consulting service	----	----	3,184.99	----	
Dam site and regional geology	----	----	----	11,542.66	11,542.66
Design by TVA	----	----	----	577,988.99	577,988.99
Total	11,498.26	----	604,862.72	696,375.60	1,312,736.58

[1] Reservoir property management.
[2] Denotes credit.

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Martin, R. E., construction plant.
Mathews, W. R., design.
Menhinick, H. L., regional studies.

Meyer, A. A., design.
Mills, R. M., materials.
Moneymaker, Berlen C., geology.
Monroe, R. A., design.
Niece, R. K., field engineering.
Norris, Crayton L., design.
Nowell, J. C., design.
Nowlin, William D., construction.
Nystrom, O. A., costs.
Okey, C. W., preliminary investigations.
Palo, G. P., design.
Patchen, Joseph C., construction.
Pauls, A. L., construction.
Perkins, R. C., construction.
Petersen, Harold J., design.
Ray, Frank W., drafting service.
Rich, George R., design.
Riegel, Ross M., design.
Roberts, K. C., design.
Rutter, E. J., flood control.
Sayford, Ned H., maps and surveys.
Scroggie, Everett, design.
Sellers, L. R., design.
Snyder, John I., land acquisition.
Sturdevant, W. L., general.
Swidler, Joseph C., legal.
Taylor, T. F., construction.
Titus, E. M., design.
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Woodbury, Edward, electrical.
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Appendix A

STATISTICAL SUMMARY

Authorized by Congress	Jan. 30, 1942
Authorized by Tennessee Valley Authority Board of Directors	Feb. 2, 1942
Construction started	Feb. 2, 1942
Dam closure (beginning of reservoir filling)	Feb. 19, 1943
First power unit (stall No. 3) on line	Mar. 21, 1943
Second power unit (stall No. 1) on line	Jan. 12, 1944

Location

On French Broad River at mile 32.3, in Sevier County, Tenn.; approximately 4.5 air miles from the nearest point of the Tennessee & North Carolina Railroad between Knoxville and Sevierville; 6.5 air miles north of Sevierville; 26 air miles east of Knoxville.

PRINCIPAL DESIGN FEATURES

STREAM FLOW

Drainage area at dam	4,541 square miles
Average annual precipitation on drainage area above dam site	47 inches
Gaging station records:	
Dandridge, Tenn., October 1918 to date	4,446 square miles
At Knoxville, Tenn., January 1899 to date	8,934 square miles
Maximum flow of record:	
At Dandridge, May 1901, estimated	140,000 cubic feet per second
Average flow at dam site (1918–43)	6,700 cubic feet per second
Minimum daily flow of record (September 1925)	370 cubic feet per second
Maximum estimated flow (design flood)	337,000 cubic feet per second

RESERVOIR

Counties affected:	
State of Tennessee	Sevier, Jefferson, Cocke, Hamblen
Operating levels at dam:	
Maximum assumed for design	Elevation 1002
Top of gates (area 31,600 acres)	Elevation 1002
Normal maximum pool level (area 30,600 acres)	Elevation 1000
Spillway crest (area 19,700 acres)	Elevation 970
Minimum (area 5,360 acres)	Elevation 920
Length (backwater) at elevation 1000	43.1 miles
Length of shore line at elevation 1000:	
Main shore	492 miles
Islands	73 miles
Total	565 miles
Original river area at elevation 1002	3,170 acres
Storage (flat pool assumption):	
Total volume at elevation 1002 (top of gates)	1,514,100 acre-feet
Volume at elevation 1000	1,452,000 acre-feet
Volume for low-water releases (elevation 1002–920)	1,452,000 acre-feet
Volume at maximum draw-down (elevation 920)	94,000 acre-feet
Controlled flood storage on Mar. 15 (elevation 1,002–958)	1,019,800 acre-feet

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Tailwater

Maximum design level (337,000 cubic feet per second)	Elevation 919
Maximum level of record (150,000 cubic feet per second)	Elevation 901
Average level (6,820 cubic feet per second)	Elevation 873
Minimum	Elevation 870

Head (Gross)

Average (elevation 1000–872)	128 feet
Minimum (elevation 935–872)	63 feet
Maximum (elevation 1002–870)	132 feet

Preparation for Flooding

Property acquired	33,160 acres
Clearing (between elevation 1002 and 920)	5,182 acres
Drainage of isolated pools	15,549 cubic yards
Highways:	
Access and construction roads	22.3 miles
State highways	5.3 miles
County highways and tertiary roads	52.1 miles
Total all roads	79.7 miles
Railroad adjustments	9.0 miles
Access railroad (temporary)	7.2 miles
Bridge adjustments (culverts not included)	5
Families relocated	525
Graves	2,449 removals
Utilities adjusted or constructed	204.3 miles

STRUCTURES

Lengths (along axis of dam):	
Spillway at crest (440-foot clear length)	505.0 feet
Nonoverflow concrete sections:	
Right nonoverflow section	526.5 feet
Left nonoverflow section	360.5 feet
Intake	313.0 feet
Total length concrete structures	1,705.0 feet
Earth embankments:	
Saddle dam No. 1	1,918 feet
Saddle dam No. 3	650 feet
Saddle dam No. 4	65 feet
Saddle dam No. 5	228 feet
Saddle dam No. 6	130 feet
Saddle dam No. 8	125 feet
Saddle dam No. 9	295 feet
Saddle dam No. 10	322 feet

Spillway

Type	Concrete gravity overfall section
Crest	Elevation 970
Openings	11 openings, each 40 feet wide
Piers	10 piers, each 6 feet 6 inches thick
Energy dissipation	Reinforced concrete stilling pool, 183 by 505 feet
Discharge capacity (including sluices but not turbines)	354,000 cubic feet per second.

Power Plant

Intake:

Four semicircular reinforced concrete towers on upstream face of dam.

Powerhouse:

Type — Semioutdoor type, structural steel and reinforced concrete construction.

Size — 238 feet long, 95 feet wide, 93 feet high (bedrock to deck floor)

Units:

Initial	Two 30,000-kilowatt generators
Ultimate	Two 30,000-kilowatt and two 26,000-kilowatt generators

Switchyard:

Location	North of and adjacent to powerhouse
Size (fence enclosure)	154-kilovolt yard, 199½ by 246 feet; 110-kilovolt yard, 100 by 115 feet.

CONSTRUCTION QUANTITIES (PERMANENT FEATURES ONLY)

Dam

Excavation:	
Earth	172,300 cubic yards
Rock	332,800 cubic yards
Total	505,100 cubic yards
Fill:	
Earth	56,300 cubic yards
Rock	60,000 cubic yards
Total	116,300 cubic yards
Reinforcing steel	3,500 tons
Structural steel	2,900 tons
Concrete	548,200 cubic yards
Formwork	1,253,000 square feet
Riprap	11,600 cubic yards

Saddle dams and dike

Excavation:	
Earth	113,500 cubic yards
Rock	4,100 cubic yards
Fill:	
Earth	693,000 cubic yards
Rock	15,200 cubic yards
Concrete	3,810 cubic yards
Riprap	89,000 cubic yards

DETAILS OF STRUCTURES

EMBANKMENTS

SADDLE DAM NO. 1

Height (maximum) — 95 feet
Width:
Top — 20 feet
Base — 670 feet
Length along crest — 1,918 feet
Construction — Impervious rolled earth fill with internal drainage system; upstream side protected by 3 feet of riprap on a 1-foot layer of gravel; downstream side seeded.
Slopes:
Upstream — To elevation 1,000, 1 on 4.5; above elevation 1000, 1 on 2.5
Downstream — To elevation 982, 1 on 3; above elevation 982, 1 on 2.5
Earth excavation — 29,707 cubic yards
Earth fill, rolled — 473,924 cubic yards
Rock fill, including drainage — 13,933 cubic yards
Riprap — 62,155 cubic yards

SADDLE DAM NO. 2

Not constructed — See p. 45

SADDLE DAM NO. 3

Height (maximum) — 32 feet
Width:
Top — 20 feet
Base — 275 feet
Length along crest — 650 feet
Construction — Similar to saddle dam No. 1
Slopes:
Upstream — To elevation 1000, 1 on 4.5; above elevation 1000, 1 on 2.5
Downstream — To elevation 982, 1 on 3; above elevation 982, 1 on 2.5
Earth excavation — 10,069 cubic yards
Earth fill — 33,107 cubic yards
Rock fill, including drainage — 1,311 cubic yards
Riprap — 5,617 cubic yards

Saddle Dam No. 4

Height (maximum) 25 feet
Width:
  Top 20 feet
  Base 172 feet
Length along crest 65 feet
Construction Similar to saddle dam No. 1, except that internal drainage system is omitted.
Slopes:
  Upstream To elevation 1000, 1 on 4.5; above elevation 1000, 1 on 2.5
  Downstream To elevation 982, 1 on 3; above elevation 982, 1 on 2.5
Earth excavation 1,007 cubic yards
Earth fill 439 cubic yards
Riprap 180 cubic yards

Saddle Dam No. 5

Height (maximum) 25 feet
Width:
  Top 20 feet
  Base 172 feet
Length along crest 228 feet
Construction Similar to saddle dam No. 4
Slopes:
  Upstream To elevation 1000, 1 on 4.5; above elevation 1000, 1 on 2.5
  Downstream To elevation 982, 1 on 3; above elevation 982, 1 on 2.5
Earth excavation 3,532 cubic yards
Earth fill 9,338 cubic yards
Riprap 2,197 cubic yards

Saddle Dam No. 6

Height (maximum) 18 feet
Width:
  Top 20 feet
  Base 110 feet
Length along crest 130 feet
Construction Similar to saddle dam No. 4
Slopes:
  Upstream To elevation 1000, 1 on 4.5; above elevation 1000, 1 on 2.5
  Downstream To elevation 982, 1 on 3; above elevation 982, 1 on 2.5
Earth excavation 2,014 cubic yards
Earth fill 2,207 cubic yards
Riprap 467 cubic yards

Saddle Dam No. 7

Not constructed See p. 45

Saddle Dam No. 8

Height (maximum) 18 feet
Width:
  Top 20 feet
  Base 110 feet
Length along crest 125 feet
Construction Similar to saddle dam No. 4
Slopes:
  Upstream To elevation 1000, 1 on 4.5; above elevation 1000, 1 on 2.5
  Downstream To elevation 982, 1 on 3; above elevation 982, 1 on 2.5
Earth excavation 1,936 cubic yards
Earth fill 549 cubic yards
Riprap 159 cubic yards

Saddle Dam No. 9

Height (maximum) 18 feet
Width:
  Top 20 feet
  Base 110 feet
Length along crest 295 feet
Construction Similar to saddle dam No. 4

Slopes:
Upstream........ To elevation 1000, 1 on 4.5; above elevation 1000, 1 on 2.5
Downstream........ To elevation 982, 1 on 3; above elevation 982, 1 on 2.5
Earth excavation.................................... 4,570 cubic yards
Earth fill.................................... 5,232 cubic yards
Riprap.................................... 1,572 cubic yards

Saddle Dam No. 10

Height (maximum).................................... 18 feet
Width:
Top.................................... 20 feet
Base.................................... 110 feet
Length along crest.................................... 322 feet
Construction....................................Similar to saddle dam No. 4
Slopes:
Upstream........ To elevation 1000, 1 on 4.5; above elevation 1000, 1 on 2.5
Downstream........ To elevation 982, 1 on 3; above elevation 982, 1 on 2.5
Earth excavation.................................... 4,988 cubic yards
Earth fill.................................... 6,984 cubic yards
Riprap.................................... 2,224 cubic yards

NONOVERFLOW CONCRETE DAM

Type and foundation............ Gravity section on Knox dolomite foundation
Length:
Right (north) nonoverflow section.................................... 526.5 feet
Left (south) nonoverflow section.................................... 360.5 feet
Intake section.................................... 313.0 feet
Total.................................... 1,200 feet
Height, lowest foundation to deck.................................... 165 feet
Slope of concrete:
Upstream.................................... Vertical
Downstream.................... 10 on 7 to elevation 988.52, vertical above
Uplift...... Assumed to act on two-thirds of the base area, varying uniformly from headwater pressure at the heel to 50 percent of headwater pressure at the drains, and decreasing uniformly from the drains to tailwater pressure at the toe of the dam.
Deck elevation.................................... Elevation 1009

SPILLWAY

Type.................................... Concrete gravity overfall section
Length...... 11 openings, each 40 feet long; 10 reinforced concrete piers, each 6 feet 6 inches thick; total length, 505 feet.
Height, lowest foundation to operating deck.................................... 202 feet
Crest elevation.................................... Elevation 970
Discharge capacity cubic feet per second, reservoir at elevation 1002:
Crest.................................... 325,000
Sluices.................................... 29,400
Base thickness:
Overflow weir.................................... 127.2 feet
Pier.................................... 67 feet
Including apron.................................... 310.2 feet
Apron:
Top elevation, stepped apron.................................... Elevation 855 to 866
Top elevation, level apron.... Maximum elevation, 855.0; minimum elevation, 830.0.
Thickness (minimum).................................... 5 feet
Length from base line.................................... 312.4 feet
Baffle wall, stepped apron.................................... Top at elevation 870
Baffle wall, level apron.................................... Top at elevation 855
Gates:
Type.................................... Radial steel
Number.................................... 11
Clear opening between piers.................................... 40 feet
Height.................................... 32 feet

Training Walls

Right (north) wall — Reinforced concrete cantilever
Length from base line — 312.4 feet
Top elevation — 900
Left (south) wall — Concrete lining placed against rock
Length from base line — 312.4 feet
Top elevation — 883

Traveling Gate Hoist

Number — 2
Manufacturer — Philips & Davies, Inc.
Location — Mounted on spillway deck
Gate lifting load — 112,000 pounds
Capacity and speeds:
Hoist capacity (both drums) — 120,000 pounds
Lifting speed — 8.43 feet per minute
Maximum lift — 31 feet 8 inches
Travel speed — 62.6 feet per minute
Maximum travel — 465 feet
Motors (440 volts, 3-phase, 60 cycles):
Main hoist — Open, high-slip, squirrel-cage, 40-horsepower, 600 revolutions per minute.
Travel — Open, high-slip, squirrel-cage, 5-horsepower, 900 revolutions per minute.
Brakes:
Hoist — 2-thrustor type, torque rating 600 pound-feet each
Travel — 1 disc-type, torque rating 50 pound-feet
Reel — 1 disc-type, torque rating 50 pound-feet

Sluices

Number — 8
Location — In spillway blocks 18 to 21 and 24 to 27, inclusive
Type — Steel lining upstream 40 feet; unlined below
Dimensions — Opening 5 feet 8 inches wide by 10 feet high
Capacity of 1 sluice (headwater at elevation 1002) — 3,675 cubic feet per second.
Gates:
Manufacturer — Hardie-Tynes Manufacturing Co.
Number and type — 16—two slide gates installed in tandem in each of 8 sluiceways; upstream gate for emergency use; downstream gate for service use.
Operating mechanism — 24 inches in diameter, oil-operated hydraulic hoist mounted above bonnet.
Air vents per gage — 2 inlets, 8 inches in diameter, connected by header to 12-inch pipe.
Maximum head on gate — 124 feet above gate sill
Weight of 1 gate — 90,000 pounds
Trashracks:
Number — 8 (1 per opening)
Dimensions of sections — Semicircular section 6-foot 4-inch radius, 21 feet 1½ inches high.
Size of bars — 1½- and 1¼-inch square bars spaced 18 inches on centers

POWER PLANT

INTAKE

Number of openings — 4; 1 for each turbine, 14 feet 8 inches wide by 24 feet 4 inches high.
Type — Straight gravity-type concrete structure, independently stable
Trashrack structure:
Number — 4
Dimensions — 4 equal chords forming a semicircle of 13-foot radius. Foundation structure is 85 feet high and trashrack 65 feet high.
Gross area — 1,780 square feet

Trashracks:
- Number — 4 per structure, each in 5 sections
- Size of sections — 8 feet 4⅞ inches wide by 12 feet 11⅝ inches high
- Size of bars — Vertical bars 4 by ⅝ inch spaced 6 inches on centers, horizontal bars 6 by ⅝ inch at top and bottom, and 6- by ¾-inch intermediate horizontal bars 2 feet 7 inches on centers.

Gates:
- Number and type — 3 tractor-type gates, 1 installed in the penstock opening of each of the 3 authorized units.
- Dimensions — 20 feet by 30 feet 3⅜ inches over-all
- Weight — 108,000 pounds
- Maximum head — 105 *feet above center line of penstock opening*
- Hoist — Fixed chain-type electric-motor drive
- Air vents — 4 corrugated pipe vents 30 inches in diameter, 1 for each penstock.

Gate hoists:
- Number — 3, 1 for each authorized unit
- Type — Fixed chain-type electric motor drive
- Location — In hoist chamber in dam
- Capacity — Lowering load, 130 tons; raising load, 60 tons
- Speed — 8.3 feet per minute raise, 10.1 feet per minute lower
- Maximum lift — 86 feet
- Motors (440 volts, 3-phase, 60-cycles) — 1 per hoist, 50-horsepower, 1,800/1,620 revolutions per minute splashproof, high-slip, squirrel-cage.
- Brakes — 2 thrustor brakes, torque rating 190 pound-feet each

Penstocks

- Number — 4
- Type — Steel-lined for lower 60 feet only
- Dimensions — 19 feet in diameter and 123 feet long; spacing 61 feet on centers
- Air vents — 1 for each penstock
- Bulkhead — A temporary steel bulkhead placed in the penstock openings of units 2 and 4.

POWERHOUSE

Powerhouse superstructure completed for 3 units, substructure stall for fourth unit.

Generating capacity (rated):
- Initial installation — 60,000 kilowatts in 2 units, a third unit authorized but deferred.
- Ultimate installation — 112,000 kilowatts in 4 units, two 26,000-kilowatt and two 30,000-kilowatt capacity.

Principal dimensions (3-unit installation):
- Length — 238 feet
- Width — 95 feet
- Maximum height (foundation to deck floor) — 93 feet
- Concrete — 41,880 cubic yards
- Structural steel — 778 tons

Control Building

Principal dimensions:
- Length — 158 feet
- Width — 55 feet
- Maximum height (above deck) — 24 feet

Type — Reinforced concrete

Draft Tubes

- Number — 4
- Type — Concrete elbow, circular section at upper end changing to 2 rectangular passages at discharge point.
- Draft tube liner — Circular steel plate ⅝ inch thick extending about 4 feet down from top of draft tube; diameter at top 16 feet 3 inches.
- Horizontal length (center line of turbine to downstream face) — 59 feet
- Pier — Center pier of concrete 6 feet thick
- Outlet dimensions (each half) — 20 feet 3 inches wide by 15 feet 9 inches high at outer side and 13 feet 5½ inches high at pier.
- Net area outlet opening (total for 1 unit) — 592 square feet

Gates------1 set of 2 gates furnished, 13 feet 5 inches high by 20 feet 3 inches clear opening between piers; gates of steel construction.
Bulkheads------3 sets of 2, 13 feet 7¼ inches high by 22 feet wide, of timber and steel construction.

TURBINES

Number---------- 2 initially, 4 ultimately
Manufacturer---------- S. Morgan Smith Co.
Type---------- Vertical Francis reaction
Rating (initial units only)---------- 41,500 horsepower at 100-foot head
Spacing---------- 61 feet
Efficiencies:

Net head	Full-gate capacity (horsepower)	Guaranteed efficiency (percent)				
		At full load	41,500 horsepower	35,000 horsepower	30,000 horsepower	20,000 horsepower
130 feet	50, 000	86. 5	83. 3	80. 0	77. 0	68. 5
125 feet	50, 000	90. 0	87. 1	84. 0	81. 7	72. 7
110 feet	49, 100	84. 0	90. 0	87. 0	84. 6	77. 0
100 feet	41, 500	82. 7	82. 0	87. 8	85. 4	78. 0
75 feet	23, 000	74. 0	--------	--------	--------	--------
62 feet	9, 000	50. 0	--------	--------	--------	--------

Normal speed---------- 94.7 revolutions per minute
Runaway speed---------- 189 revolutions per minute
Specific speed---------- 61 revolutions per minute
Discharge at full gate and 100-foot head---------- 4,700 cubic feet per second
Water velocities, full gate, 100-foot head:
- Trashracks---------- 2.55 feet per second
- Intake gates---------- 13.3 feet per second
- Scroll case entrance---------- 17.3 feet per second
- Draft tube exit---------- 7.8 feet per second

Runner---------- 15 buckets, vertical Francis; cast steel, 177 inches in diameter (outlet).
Main shaft---------- Forged steel, 12 feet 6⅞ inches long 33 inches in diameter
Speed ring---------- Cast steel, 20 stationary vanes, 20 wicket gates
Dimensions:
- Inside diameter---------- 18 feet 4 inches
- Height (over-all)---------- 7 feet 8 inches
- Wicket gate height---------- 4 feet 7$^{11}/_{16}$ inches

Guide bearing---------- Oil lubricated, gravity feed, babbitt lined
Clearances:
- Top seal---------- ⅛ inch
- Bottom seal---------- $^{5}/_{64}$ inch
- Wicket gates (total top and bottom)---------- $^{1}/_{16}$ inch

Scroll case---------- Riveted plate steel
Guide vane servomotor cylinders------ 2 for each turbine, 22 inches in diameter, 18⅝-inch stroke, volume 13,640 cubic inches.
Approximate weight of principal parts:
- Embedded parts:
  - Scroll case---------- 292,000 pounds
  - Speed ring---------- 111,000 pounds
  - Draft-tube liner---------- 17,000 pounds
  - Curb ring---------- 23,150 pounds
  - Pit liner---------- 20,000 pounds

Approximate weight of principal parts—Continued
Internal and operating parts:
Bottom plate .... 25,400 pounds
Top plate .... 55,600 pounds
Runner .... 108,500 pounds
Bearings and housing .... 33,800 pounds
Servomotors (both) .... 12,000 pounds
Gate ring .... 11,400 pounds
Gate links, levers, and pins .... 10,300 pounds
Wicket gates, total (20 gates) .... 49,800 pounds
Shaft .... 42,900 pounds
Total rotating parts .... 151,300 pounds
Total weight of 1 turbine .... 1,088,000 pounds
Maximum weight to be lifted by powerhouse crane .... 151,300 pounds
Maximum unbalanced hydraulic thrust .... 190,000 pounds
Total maximum turbine load on thrust bearing (rotating parts plus hydraulic thrust) .... 361,300 pounds
Flywheel effect at 1-foot radius .... 3,200,000 pounds

GOVERNORS

Number .... 2 initially, 4 ultimately
Manufacturer .... Woodward Governor Co.
Type .... Cabinet actuator
Pipe size .... 5 inches
Operating pressure:
Maximum .... 300 pounds per square inch
Minimum .... 250 pounds per square inch
Rated capacity .... 88,000 foot-pounds per second
Closing time of gates, minimum (guaranteed) .... 4 seconds
Speed droop adjustment .... 0 to 6 percent
Rated sensitivity .... 1/25 of 1 per cent
Oil pump:
Number .... 2 in each cabinet
Type .... Rotary
Rating .... 150 gallons per minute at 300-pound pressure and 900 revolutions per minute.
Motor .... 440-volt, 3-phase, 60-cycle, 40-horsepower, 900 revolutions per minute.
Maximum velocity in oil lines .... 18 feet per second
Size of cabinets:
Single unit .... 12 feet by 7 feet by 7 feet 9½ inches
Twin unit .... 19 feet by 7 feet by 7 feet 9½ inches

GENERATORS

Number .... 2 initially, 4 ultimately
Manufacturer .... General Electric Co.
Electrical characteristics:
Rating (initial units) .... Normal continuous 33,333 kilovolt-amperes at 0.9 power factor, 60° C. temperature rise, 60-cycle, 3-phase, 13,800 volts, 94.7 revolutions per minute, class B insulation. Maximum continuous 38,333 kilovolt-amperes at 0.9 power factor, 80° C. temperature rise, at 95 to 105 percent of rated voltage.
Line charging capacity .... 26,600 kilovolt-amperes
Synchronous condenser capacity .... 18,300 kilovolt-amperes
Efficiencies .... Guaranteed over-all including exciters and rheostats (100 percent load equals 33,333 kilovolt-amperes):

Load, percent	1.0 power factor				0.9 power factor			
	50	75	100	115	50	75	100	115
Efficiency, percent	96.80	97.40	97.55	97.55	96.40	97.00	97.20	97.20

Electrical characteristics—Continued

Losses in kilowatts (calculated data, 100 percent load equals 33,333 kilovolt-amperes):

	1.0 power factor				0.9 power factor			
Load, percent	50	75	100	115	50	75	100	115
Field I^2R	60	70	80	94	86	112	147	176
Friction and windage	135	135	135	135	135	135	135	135
Core	214	214	214	214	214	214	214	214
Armature I^2R	34	76	134	177	34	76	134	177
Stray load	22	50	89	102	22	50	89	102
Exciters and rheostats	12	14	15	18	16	19	24	28
Total losses	477	559	667	740	507	606	743	832

Temperature detectors:
- Stator winding — 12 resistance-type units
- Bearings — 2 units for each bearing
- Bearing oil bath — 1
- Generator coolers — 8
- Exciter air discharge — 1

Reactances:
- Direct axis synchronous — 100 percent
- Direct axis transient — 41 percent
- Direct axis subtransient — 31 percent
- Quadrature axis transient — 66 percent
- Quadrature axis subtransient — 40 percent
- Negative sequence — 35 percent
- Stator leakage — 20 percent
- Zero sequence — 18 percent

Resistances:
- Stator winding, per phase, at 75° C — 0. 023 ohm
- Field winding, at 75° C — 0. 228 ohm

Short-circuit ratio — 1. 1

Symmetrical rms short-circuit currents calculated by manufacturer (ratio to rated current):
- Initial 3-phase — 3. 23
- Initial single-phase — 2. 63
- Initial line to neutral — 3. 57
- Sustained 3-phase — 1. 20
- Sustained single-phase — 1. 46
- Sustained line to neutral — 2. 19

Voltage regulator — Automatic, high speed, noncontinuous vibrating with cross-current compensation.

Full load regulation at rated voltage and speed — 24 percent of rated voltage between full load and no load at 0.9 power factor.

Time response of voltage regulator — 3 cycles

Field currents:
- Full load, 0.9 power factor — 800 amperes
- Full load, 1.0 power factor — 594 amperes
- Operating as condenser, overexcited maximum — 800 amperes

Stator — Y-connected, split windings

Rotor, number of poles — 76

Damper windings — Noncontinuous type

Generator mechanical characteristics:

Drive — Vertical, with direct connection to turbine shaft

Rotation — Counterclockwise

Brakes — 6 shoes mounted on lower bearing bracket, bearing against lower rim of rotor; operated by 90 to 100 pounds air pressure; designed to bring unit to full stop from half speed within 8 minutes.

Jacks — Brakes may be used as jacks; operated by oil with hand pump at high pressure; designed to lift rotor sufficient for bearing part inspection and removal.

Ventilation and cooling:
- Number of coolers — 8
- Cooling water — Maximum flow 600 gallons per minute at 20° C.

Generator mechanical characteristics—Continued
Flywheel effect (WR^2) — 45,000,000 pound-feet^2
Bearings and lubrication:
Type — Combination Kingsbury-type thrust bearing and segmental guide bearing located below the generator rotor.
Thrust-bearing capacity — 900,000 pounds
Lubrication: Capacity of oil reservoir — 1,200 gallons
Oil characteristics:
Viscosity seconds Saybolt Universal:
At 40° Fahrenheit — 1900
At 100° Fahrenheit — 244
Viscosity index — 77
Cooling — Cooled by circulating water, 100 gallons per minute at 20° C.
Shaft — Forged steel shaft 33 inches in diameter; hollow-bored with 6-inch diameter; flange connection to turbine shaft.
Dimensions:
Diameter of housing — 38 feet 4 inches
Diameter of stator — 31 feet 8 inches
Diameter of rotor — 26 feet 4⅞ inches
Height of generator including exciters — 13 feet 9¼ inches
Weight of principal parts (calculated net weights):
Rotor without shaft — 370, 000 pounds
Shaft — 80, 000 pounds
Bearings and lower bracket — 150, 000 pounds
Stator without coolers and housing — 200, 000 pounds
Main exciter — 31, 000 pounds
Pilot exciter — 5, 300 pounds
Main generator complete — 955, 000 pounds

EXCITERS

Main exciter:
Type — Shunt-wound, 10 poles, separately excited, direct-connected
Rating — 220 kilowatts, 250 volts, 880 amperes, 94.7 revolutions per minute
Mounting — Vertical, on shaft above generator
Ceiling voltage — 325 volts
Nominal response ratio — 1.0
Insulation — Class A
Pilot exciter:
Type — Compound wound, self-excited, direct connected
Rating — 17 kilowatts, 250 volts, 68 amperes, 94.7 revolutions per minute
Insulation — Class A

GENERATOR AUXILIARY EQUIPMENT

Generator neutral reactor:
Number — 1 for each generator
Type — Self-cooled, open coil, air core
Rating — 15,000-volt insulation, reactance 1 ohm, 1-minute rating of 4,000 amperes, temperature rise 195° C.
Mounting — Steel cubicle
Generator neutral oil circuit breaker:
Number — 1 for each generator
Type — FK–158B
Rating — 600 amperes, 15,000 volts, 150,000 kilovolt-amperes interrupting capacity.
Generator surge protective arrester:
Number — 6
Manufacturer — General Electric Co.
Type — Single pole, special
Rating — 13.8 kilovolts, line-to-line
Guaranteed performance data:
Maximum permissible voltage, line-to-ground — 12 kilovolts, rms
Maximum voltage, line-to-line — 15 kilovolts, rms
Impulse voltage to start discharge with 1.5 x 40 microsecond wave average crest — 39 kilovolts
Impulse voltage to start discharge with AIEE standard impulse test average crest — 43 kilovolts

Generator surge protective arrester—Continued
Guaranteed performance data—Continued
Arrester cut-off or reseal voltage, line-to-ground---------- 12 kilovolts
IR drop on 10 x 20 microsecond current wave of 1,500 amperes------ 37 kilovolts, crest.

Metal-clad Switch Gear

Generator metal-clad switch gear:
Number-- 1 for each generator
Type------ Steel housing with asbestos cement barriers, enclosing current transformers, potential transformers, surge protective arresters, disconnecting switches, busses, insulators, and cable terminals.
Rating-- 15 kilovolts
Size of bus-------------------------- 3¼- by 4-inch copper bars per phase
Bus insulators--------------------------- 15 kilovolts, NEMA, class B–3
Maximum short-circuit bus current----------------------- 24,000 amperes
Oil circuit breaker cubicle:
Number-- 1 for each generator
Manufacturer----------------------- Allis-Chalmers Manufacturing Co.
Type------------------------- Steel housing enclosing oil circuit breaker
Rating-- 15 kilovolts
Breaker------ 2,000 amperes, 3 poles, 1,000,000 kilovolt-amperes interrupting capacity, electrically operated.

Main Control Switchboards

Type------⅛-inch thick, stretcher-leveled steel, dead-front panels, for all boards

	Panels	
	Number	*Width*
Benchboard	7	2 feet 4 inches
Instrument board	7	2 feet 4 inches
Relay board	7	2 feet 4 inches
DC. battery board	5	2 feet 0 inch
Recording board	6	2 feet 0 inch

Annunciator system:
Number------ 14 illuminated visual annunciator windows and a large illuminated unit numeral are provided for each generator on the respective actuator control boards with audible alarm signals mounted inside the actuator cabinets.
Operation------ The annunciator and transmitter circuits on 48-volt direct current; recorder circuit on 250-volt direct current; supervisory circuits on 115-volt alternating current.
Load and frequency-control equipment:
Principal equipment:
1------ Motor-generator set; alternating-current generator, 3.75 kilovolt-ampere; direct-current motor, 5 horsepower, 258 volts, 1,800 revolutions per minute.
1---------------------------------- Station-load recorder
1---------------------------------- Tie-line load recorder controller
1-- Frequency controller
2-- Unit-load controllers
Selector switches and auxiliary devices.
Station control battery and chargers:
Number of cells-- 120
Type of cells—lead plate------------------------ 11-plate, glass-jar type
Ampere-hour capacity of cells------ 250-volt, 50 amperes for 8 hours to final voltage of 1.75 per cell.
Number of chargers-- 2
Type of chargers-------------------------------------- Motor generator
Rating of chargers:
Motor-------- 30-horsepower, induction type, 440–volt, 3-phase, 60-cycle
Generator------20-kilowatt, diverter-pole type, direct current, maximum voltage 300.
Carrier-current telephone equipment:
Principal equipment:
1------ Transmitter-receiver unit, with 2 local extension lines, using 154-volt transmission lines as the conducting medium.

AUXILIARY POWER

Main station service power transformers:

- Number — 2
- Manufacturer — Allis-Chalmers Manufacturing Co.
- Type — Indoor, self-cooled, noninflammable, liquid-filled
- Rating — 1,000-kilovolt-ampere, 3-phase, 13,200–480-volt, 60-cycle, 55° C. rise.
- Connection — High side wye with ungrounded neutral, low side delta
- Taps — Three 2½ percent above and one below 13,200 volts, full capacity
- Manufacturer's test data at 75° C., rated voltage, and rated frequency, average values:
  - Impedance — 6.07 percent
  - Exciting current — 2.03 percent
  - No-load losses — 3,385 watts
  - Total losses — 9,890 watts
  - Regulation:

Percent power factor	100	90	80
Percent regulation	0.83	3.36	4.30

  - Efficiency at 100 percent power factor:

Percent load	100	75	50	25
Percent efficiency	99.02	99.07	99.00	98.50

- Segregated weights:
  - Core and coils — 8,000 pounds
  - Tank and fittings — 3,100 pounds
  - Liquid (415 gallons Chlorextol) — 5,450 pounds
  - Total — 16,550 pounds
- Dimensions:
  - Projected floor space — 55 by 80 inches
  - Height over tank — 90½ inches
  - Headroom for untaking — 182 inches

Emergency auxiliary power generator:

- Number — 1
- Manufacturer:
  - Gasoline engine — Buffalo Gasoline Motor Co.
  - Generator — Westinghouse Electric & Manufacturing Co.
- Type — Direct-coupled, common bedplate
- Engine rating — 290-brake horsepower at 1,200 revolutions per minute, 8-cylinder, 6½-inch bore, 7 inch stroke, 12-volt starters.
- Fuel consumption per kilowatt-hour:

Percent load	100	75	50
Pounds of fuel	0.94	0.98	1.15

- Generator rating — 200-kilovolt-ampere, 80-percent power factor, 3-phase, 480-volt, 60-cycle.
- Generator regulation:
  - Unity power factor — 25 percent
  - 80 percent power factor — 40 percent
- Generator efficiency at unity power factor:

Percent load	100	75	50
Percent efficiency	94.3	93.6	91.5

- Exciter rating — 125-volt, 24-ampere
- Total weight of engine-generator set — 16,300 pounds
- Dimensions of engine-generator set:
  - Projected floor space — 39 by 173¼ inches
  - Height — 65½ inches

Powerhouse lighting transformers:

- Number — 2
- Manufacturer — General Electric Co.
- Type — Standard distribution, noninflammable, liquid-filled
- Rating — 100 kilovolt-ampere, 480–240/120-volt, single-phase, 60-cycle
- Connections — Single-phase, 3-wire
- Primary taps — Two 5-percent full-capacity taps below normal
- Weight — 2,420 pounds

Auxiliary power switchboards:
- Main 440-volt auxiliary power board:
  - Location------ Elevation 900 floor in room with 2 station service transformers.
  - Equipment—carbon circuit breakers for:
    - 3------ Supply circuits for station service transformer and emergency generator.
    - 1------ Bus tie
    - 2------ Circuits to common auxiliary power board
    - 4------ Circuits to unit auxiliary power boards
    - 7------ Outgoing circuits to air-conditioning auxiliary power board, sump pump motor, powerhouse crane, station lighting transformer, intake dam, spillway dam.
- Common 440-volt auxiliary power board:
  - Location------ Elevation 914 floor in electrical bay
  - Equipment:
    - Double-throw unfused knife switches for connections to incoming supply cables.
    - Fused knife switches for control of station auxiliaries.
- 440-volt unit auxiliary power boards:
  - Location------ Elevation 900 floor in electrical bay
  - Equipment:
    - Each unit board has 2 possible supply circuits and has branch circuits for governor oil pump motor, generator room heaters, generator housing heaters, power receptacles, 2 transformers for Selsyn-type position indicators, turbine bearing oil pumps.
- 440-volt air-conditioning board:
  - Location------ Elevation 939 floor in air-conditioning room
  - Equipment:
    - Single supply circuit which may be energized from either 440-volt bus at main auxiliary power board or from emergency auxiliary generator. Power circuits for heating, ventilating, and air-conditioning equipment.
- Station lighting and heating board:
  - Location------ Elevation 914 floor in room of electrical bay
  - Equipment:
    - 2-pole, double-throw knife switches connecting 2 lighting buses to lighting transformers.
    - 2-pole, fused knife switches feeding lighting cabinets and heater cabinets.
- 440-volt emergency generator control board:
  - Location------ Elevation 900 floor in separate room
  - Equipment:
    - Indicating instruments, voltage regulator, generator breaker, field switch, field rheostat.

FIRE PROTECTION

Carbon dioxide system:
- Number of systems------ 2
- Equipment:
  - System No. 1.—Protection of generators------ Air space within each machine 14,000 cubic feet; twenty 50-pound cylinders for initial discharge; fourteen 50-pound cylinders for delayed discharge; twenty 50-pound cylinders for reserve initial discharge.
  - System No. 2.—Protection of oil storage, oil purification, and gas-electric generator set rooms: Air space—oil storage room—19,000 cubic feet; air space—oil purification room—6,750 cubic feet; air space—gas-electric generator room—6,760 cubic feet; simultaneous discharge of eighteen 50-pound cylinders into the oil storage room, or nine 50-pound cylinders into each of the other 2 rooms.
  - Portable equipment------ Thirteen 2-pound, one 10-pound, and sixteen 15-pound hand-type fire extinguishers located conveniently throughout the powerhouse; one 100-pound buggy-type carbon dioxide unit in the switchyard.

Water system:

Treated water is supplied, by gravity, for fire protection in both the powerhouse and switchyard.

Fire hydrants:

Number ---------- 3
Size ---------- 4 inches with two 2½-inch outlets
Location ---------- Switchyard

Fire-hose outlets:

Number ---------- 7
Size ---------- 1½ inch
Location ---------- Powerhouse

In addition, there are nineteen 1-inch outlets scattered throughout the powerhouse and 11 in the spillway gallery. Three 25-foot lengths of 1-inch rubber hose are provided for these outlets.

Heating, Ventilating, and Air-Conditioning Systems

Heating system:

Total connected heating load in powerhouse ---------- 402 kilowatts

Ventilating system:

Fans:

Designation	Fan: Cubic feet per minute	Fan: Static pressure	Motor horsepower
		Inches	
[illegible]	3,500	¼	½
[illegible]	38,500	⅞	10
Main supply fan No. 2	58,000	⅞	15
Toilet exhaust fan No. 1	5,400	2	3
Toilet exhaust fan No. 2	5,000	½	1
Battery room exhaust fan	2,600	2	1½
Electric bay exhaust fan	40,000	½	7½
Service bay exhaust fan	17,000	⅝	5
Attic exhaust fan	12,000	1	4½
Turbine pit supply fan (3)	1,650	⅛	⅛

All fans are centrifugal blower type except the turbine pit supply fans, which are propeller type.

All motors are 440-volt, 3-phase, 60-cycle except those for the propeller type, which are 110-volt, single-phase, 60-cycle.

Air-conditioning system:

Fans

Zone	Fan: Cubic feet per minute	Fan: Static pressure	Motor horsepower
		Inches	
Control room	5,200	1⅝	2
Offices	8,600	1¾	5
First-aid and telephone room	2,600	1	1

Refrigerating machinery:

Number ---------- 1 unit
Type ---------- Freon—12 compressor
Capacity ---------- 56.25 tons
Motor rating ---------- 75-horsepower, 440-volt, 3-phase, 60-cycle

Other equipment:

Condenser pump------- Centrifugal, single-stage, single suction, 150 gallons per minute at 20 feet.

Condenser pump motor----- 1½-horsepower, 440-volt, 3-phase, 60-cycle, 1,150 revolutions per minute.

Chilled water pump------ Centrifugal, single-stage, single-suction, 135 gallons per minute at 125 feet.

Chilled water pump motor------ 7½-horsepower, 440-volt, 3-phase, 60-cycle, 3,460 revolutions per minute.

Drainage and Unwatering System

Equipment:

Item	Station drainage pumps	Installed unwatering pump	Spare unwatering pump
Number	2	1	1.
Manufacturer	Peerless Pump Division of Food-Machinery Corp.	Peerless Pump Division of Food-Machinery Corp.	Peerless Pump Division of Food-Machinery Corp.
Capacity, gallons per minute.	300	3,000	3,000.
Head, feet	50	54	54.
Type	Deep-well turbine	Deep-well turbine	Deep-well turbine.
Number of stages	3	3	3.
Motor, manufacturer	General Electric	General Electric	General Electric.
Motor, 440 volts, 3-phase, 60 cycles.	7½ horsepower (1,750 revolutions per minute).	75 horsepower (1,175 revolutions per minute).	60 horsepower.

Treated-Water System

Source and location------ Water is obtained from a spring located approximately 4,000 feet northeast of dam. Pumping station and treatment plant located directly over spring.

Equipment:

2 service pumps------ 75 gallons per minute at 345-foot total dynamic head, Fairbanks, Morse Co.

Motors------ 15-horsepower, 440-volt, 3-phase, 60-cycle, 3,450 revolutions per minute, Fairbanks, Morse Co.

Accessories------ 2 each of float switches, fused switches and starters, and push buttons.

1 hypochlorinator------ Proportioneers solution feeder, heavy-duty midget Chlor-O-Feeders, capacity 0 to 6.5 gallons per hour, manually controlled, driven by a ⅙-horsepower, 110-volt, 1-phase, 60-cycle motor with accessories.

1 Calgon feeder------ Proportioneers solution feeder, heavy-duty midget Chlor-O-Feeders, capacity 0 to 6.5 gallons per hour, manually controlled, driven by a ⅙-horsepower, 110-volt, 1-phase, 60-cycle motor with accessories.

1 spare solution feeder------ Proportioneers solution feeder, heavy-duty midget Chlor-O-Feeders, capacity 0 to 6.5 gallons per hour, manually controlled, driven by a ⅙-horsepower, 110-volt, 1-phase, 60-cycle motor with accessories.

1 electric heater-- 5 kilowatts

1 elevated storage tank--------------------- Steel, capacity 50,000 gallons

Raw-Water System

Source-- Unit penstocks

Flow--- Gravity

Oil Systems

Equipment:

Oil purifiers:

Item	Insulating oil purifier	Governor and lubricating oil purifier
Number	1	1.
Manufacturer	De Laval Separator Co	De Laval Separator Co.
Capacity, gallons per hour	600 without press, 900 with press	350.
Filter press capacity	1,200 gallons per hour	
Heater	36 kilowatts	18 kilowatts.
Pump motor, manufacturer	General Electric	General Electric.
Pump motor, 440 volts, 3-phase, 60 cycles.	5 horsepower (1,735 revolutions per minute).	2 horsepower (1,740 revolutions per minute).
Centrifuge motor, manufacturer	General Electric	
Centrifuge motor	2 horsepower (1,740 revolutions per minute).	(Same motor as above.)

Oil pumps:

Item	Insulating oil	Governor and lubricating oil	Sluice gate oil
Number	1	2 (1 clean, 1 dirty)	2.
Manufacturer	Worthington	Worthington	Quimby.
Capacity, gallons per minute.	100	30	20.
Motor, manufacturer	Westinghouse	Westinghouse	General Electric.
Motor, 440 volts, 3-phase, 60 cycles.	15 horsepower (705 revolutions per minute).	3 horsepower (695 revolutions per minute).	25 horsepower (1,170 revolutions per minute).

Compressed-Air System

Air compressors:

Item	Stationary compressor	Portable compressor
Number	1	1.
Manufacturer	Sullivan	Sullivan.
Capacity, cubic feet per minute	105	105.
Pressure, pounds per square inch	100	100.
Cooling medium	Water	Air.
Motor, 440 volts, 3-phase, 60 cycles	25 horsepower (1,760 revolutions per minute).	25 horsepower (880 revolutions per minute).
Motor, manufacturer	General Electric	General Electric.

Powerhouse Crane

Type______ Double-trolley, traveling gantry crane, main and auxiliary hook on each trolley. Boom hoist at one corner.

Rails______ 175 pounds, 65 feet 0 inch center to center.

Motors (all 440-volt, 3-phase, 60-cycle:

- Main hoist (2)______ 50-horsepower at 600 revolutions per minute, open frame, wound rotor.
- Auxiliary hoist (2)______ 50-horsepower at 600 revolutions per minute, open frame, wound rotor.
- Gantry travel (4)______ 30-horsepower at 1,800 revolutions per minute, open frame, wound rotor, gear-motor type, 49 revolutions per minute output speed.
- Trolley travel (2)______ 10-horsepower at 900 revolutions per minute, open frame, squirrel cage.
- Boom hoist (1)______ 25-horsepower at 900 revolutions per minute, open frame, squirrel cage.
- Boom slewing (1)______ 5-horsepower at 900 revolutions per minute, open frame, squirrel cage.

Brakes:

Location	Brake	Rating, pound-feet
		Each
Cable reel (1)	Disk	10
Main hoist (2)	Thrustor	800
Auxiliary hoist (2)	do	800
Bridge travel (4)	do	160
Trolley travel (2)	Solenoid	160
Boom hoist (1)	Thrustor	400
Boom slewing (1)	Solenoid	75

Capacities and speeds:

Item	Capacity (in tons)	Speed, feet per minute	Approximate length of travel in feet	Maximum lift in feet
Main hoist	2 at 112.5	5-6		95
Auxiliary hoist	2 at 25	25-30		100
Trolley travel		25-35	31	
Gantry travel		65-75	[1] 237½	
Boom hoist	1 at 25	10-15		120
Boom slewing		180° in 1 minute		

[1] For 3 authorized units.

Service Bay Crane

Bridge:
- Type — Single I-beam and channel girder on fixed end trucks of two wheels each.
- Span — 28 feet

Hoist:
- Type — Trolley-type suspended hoist mounted on lower flange of girder
- Capacity — 5 tons
- Speed — Approximately 17 feet per minute
- Maximum lift — 20 feet

Operation:
- Trolley travel — Manually operated
- Bridge travel — Manually operated
- Hoist — Electrically operated by 6.5-horsepower motor
- Power supply — By cable reel

Passenger Elevator

Type — Gearless, automatic, electric
Capacity — 5,000 pounds live load
Motor — Direct current
Motor-generator set:
- Motor — 45 horsepower, 440 volts, 3 phase, 60 cycles, induction type
- Generator — 100 amperes, 250 volts, direct current
- Exciter generator — 14 amperes, 230 volts, direct current

Controls — Automatic push-button, single-call type
Lift — 81 feet, speed 250 feet per minute
Platform — 7 feet 2 inches by 6 feet 0 inch inside cab
Landings — Bottom elevation 928.33, top elevation 1009.0, 1 intermediate landing elevation 999.0.

Principal Machine-Shop Equipment

1 hacksaw, motor-driven, 8¼- by 9¾-inch capacity, with a 2-hp, 440-volt, 3-phase, 60-cycle, 1,200-rpm motor and 3-speed transmission.
1 bench lathe, 10 by 54 inches, driven by a ½-hp, 440-volt, 3-phase, 60-cycle, 1,725,-rpm motor.
1 portable pipe-threading machine, ½ hp, 110 volts, motor-driven, with accessories.
1 furnace, forging type, open front, coal-fired.

1 sensitive drill, 10-inch size, driven by a ⅓-hp, 440-volt, 3-phase, 60-cycle, 1,750-rpm motor.
1 tool-post grinder, with accessories, driven by a ½-hp, 110-volt, 1-phase, 60-cycle, 3,450-rpm motor.
1 pedestal grinder, 2-wheel, 12-inch size, driven by a 2-hp, 440-volt, 3-phase, 60-cycle motor.
Miscellaneous assortment of small tools.

SWITCHYARD

Steel

All structures are of galvanized structural steel; all field connections bolted; all structures designed for maximum allowable stresses in accordance with TVA structural steel standards.

Mechanical Equipment

Transformer transfer car:
- Maximum design load — 90 tons
- Maximum design wheel load — 25 tons
- Wheel base — 8 feet 9 inches
- Transfer track gage — 4 feet 8½ inches
- Transformer rail gage — 4 feet 8½ inches
- Loading winch, hand-operated, line pull — 4,000 pounds

Electrical Equipment

Main power transformers:
- Number — 3
- Manufacturer — General Electric Co.
- Type — Single-phase, oil-insulated, self-cooled and forced-air-cooled, nitrogen-gas-filled, outdoor.
- Rating — Single-phase, 20,000 kilovolt-amperes, self-cooled; 26,667 kilovolt-amperes, forced-air-cooled. All units 161,000–13,200 volts, 60 cycles, 55-degree temperature rise.
- Connections — Wye on high-voltage side with neutral grounded through reactor, delta on low-voltage side.
- Taps in high-voltage winding — Two 2½ percent above and two 2½ percent below 161,000 volts, full capacity; tap transfer, no-load manual.
- Polarity — Subtractive
- Test data (average values at 20,000 kilovolt-amperes):
  - Exciting current:
    - At 100 percent rated voltage — 2.40 percent
    - At 90 percent rated voltage — 1.17 percent
    - At 110 percent rated voltage — 5.17 percent
  - Impedance, at 75° C., 161 to 13.2 kilovolts — 10.95 percent
  - Resistance, at 75° C.:
    - 161-kilovolt windings — 0.6618 ohm
    - 13.2-kilovolt windings — 0.01469 ohm
  - Efficiency, at 75° C., 100 percent power factor:
    - Full load — 99.39 percent
    - ¾ load — 99.42 percent
    - ½ load — 99.38 percent
  - Regulation, at 75° C.:
    - 100 percent power factor — 1.00 percent
    - 90 percent power factor — 5.59 percent
    - 80 percent power factor — 7.24 percent
  - Losses, no load:
    - 110 percent rated voltage — 61 kilowatts
    - 100 percent rated voltage — 42 kilowatts
    - 90 percent rated voltage — 31 kilowatts
    - Total losses at full load, rated voltage — 122 kilowatts
- Weights of parts:
  - Tanks and fittings — 62,000 pounds
  - Core and coils — 49,000 pounds
  - Oil (8,600 gallons) — 64,000 pounds
  - Total — 175,000 pounds

Main power transformers—Continued
Dimensions:
Projected floor space __________ 15 feet 11 inches by 13 feet 9¼ inches
Height over tank __________ 17 feet 6⅛ inches
Over-all height __________ 24 feet 5 inches
Track gage __________ 4 feet 8½ inches
Bushing characteristics (withstand values in kilovolts):

Item	60-cycle dry flash-over	60-cycle wet flash-over	Impulse flash-over crest
[illegible]	50	45	110
[illegible]shing	385	310	750
[illegible] bushing	120	100	250

Neutral reactor:
Number __________ 1
Type______ Air core, oil-immersed, shielded to prevent excessive heating in tank wall, and equipped with nitrogen-gas system, outdoor type, with lightning arrester.
Manufacturer __________ General Electric Co.
Rating:
1-minute current rating __________ 800 amperes
1-minute kilovolt-ampere rating __________ 32,000 kilovolt-amperes
1-minute temperature rise __________ 120° C.
Resistance (test data) __________ 0.58 ohm
Reactance (test data) __________ 51.32 ohms
Line bushing __________ 46 kilovolts
Grounded bushing __________ 15 kilovolts
Arrester, mounted on tank __________ 40 kilovolts
Total weight __________ 7,000 pounds
Switch gear and switches:
161-kilovolt oil circuit breakers:
Number __________ 3
Manufacturer __________ General Electric Co.
Type______ 3 pole, solenoid-operated, outdoor type; all are standard nonreclosing
Rating:
Rated voltage __________ 161 kilovolts
Rated continuous current __________ 1,200 amperes
Rated frequency __________ 60 cycles
Interrupting rating at rated voltage with open-close-open 15 seconds open-close-open duty cycle __________ 2,500,000 kilovolt-amperes
Interrupting rating at rated voltage, with open-close-open 0 second open-close-open duty cycle __________ 2,125,000 kilovolt-amperes
Guaranteed performance data:
Closing time, from the instant the control switch is closed, with 250-volt direct current applied, until breaker is fully closed______ 0.67 second
Opening time, at 100 percen[illegible] rating, from instant trip circuit is energized with [illegible] current, until arc is extinguished __________ 0.23 second
1-minute, 60-cycle withstand test voltage:
Complete breaker __________ 364.25 kilovolts
Bushing __________ 315 kilovolts
Design data:
Weight, net, breaker complete with oil __________ 77,000 pounds
Weight, net, breaker without oil __________ 37,750 pounds
Oil, per complete breaker __________ 5,300 gallons
Weight, net, bushing __________ 1,480 pounds
Impact, equivalent static load, includes dead load plus impact value on opening at maximum interrupting rating __________ 237,000 pounds
Auxiliary closing relay current, with 250-volt direct current applied to mechanism control panel terminals __________ 0.8 ampere
Closing current of solenoid on 250-volt direct current______ 150 amperes
Tripping current required with 250-volt direct current applied to mechanism control terminals __________ 3 amperes

Disconnecting switches:
  161-kilovolt disconnecting switches:
    Number------ 5 manually operated, 1,200 amperes; 1 manually operated, 600 amperes, with grounding switch; 1 manually operated, 1,200 amperes, with grounding switch; 1 motor-operated, 1,200 amperes.
    Manufacturer---------------------- Electric Power Equipment Corp.
    Type--------------------- 3-pole, single-throw, outdoor, vertical-break
  15-kilovolt fused disconnecting switches:
    Number -- 2
    Manufacturer------------------------------ General Electric Co.
    Type------ Single-pole, hook-stick-operated, outdoor, vertical-break, 1-ampere current-limiting fuse.
Lightning arresters:
  Number --- 1
  Manufacturer------------------------------------ General Electric Co.
  Type-- 3-pole, station type
  Rating--- 161 kilovolts, line to line
  Guaranteed performance data:
    Maximum permissible voltage, line-to-ground------- 145 kilovolts, rms.
    Maximum voltage, line-to-line------------------- 169 kilovolts, rms.
    Impulse voltage to start discharge with 1.5 by 40 microsecond wave average crest-- 468 kilovolts
    Impulse voltage to start discharge with AIEE standard impulse test average crest-- 516 kilovolts
    Arrester cut-off or reseal voltage, line to ground----- 145 kilovolts, rms.
    IR drop on 10 by 20 microsecond current wave of 3,000 amperes----- 456 kilovolts, crest.
Line potential devices:
  Number -- 6
  Manufacturer------------------------------------- General Electric Co.
  Type-------- Pedestal-type coupling capacitor and potential device assembly, for use with carrier-current equipment.
  Rating-- 161 kilovolts, 150 watts
Line wave traps:
  Number -- 6
  Manufacturer------------------------------------- General Electric Co.
  Type------ 4 single-frequency, suspension type, 2 double-frequency, suspension type.
  Rating-------- 800-ampere capacity with 50- to 150-kilocycle tuning range
Insulators:
  Rating and type------------------------------ 38 kilovolts, pedestal type
    Number of units per stack for 161-kilovolt service------------- 4
    Manufacturer------------------------------ Porcelain Insulator Corp.
    Dry flash-over, per stack------------------------ 485 kilovolts, rms.
    Wet flash-over, per stack------------------------ 380 kilovolts, rms.
    Leakage distance, per stack---------------------------- 132 inches
    Cantilever strength, upright--------------------------- 1,200 pounds
  Rating and type------------------------------ 46 kilovolts, pedestal type
    Manufacturer------------------------------ Porcelain Insulator Corp.
    Dry flash-over------------------------------------ 170 kilovolts, rms.
    Wet flash-over------------------------------------ 125 kilovolts, rms.
    Leakage distance-- 36 inches
    Cantilever strength, upright--------------------------- 2,000 pounds
  Rating and type------------------------------ 15 kilovolts, pedestal type
    Manufacturer---------------------------- Porcelain Insulator Corp.
    Dry flash-over-------------------------------------- 85 kilovolts, rms.
    Wet flash-over-------------------------------------- 55 kilovolts, rms.
    Leakage distance-- 12 inches
    Cantilever strength, upright--------------------------- 2,000 pounds
  Rating and type--------------------------- 15 kilovolts, suspension type
    Number of units per string for 161-kilovolt service------------ 11
    Manufacturer-- Ohio Brass Co.
    Dry flash-over------------------------------------ 640 kilovolts, rms.
    Wet flash-over------------------------------------ 455 kilovolts, rms.
    Mechanical and electrical strength-------------------- 15,000 pounds

Potential coordination gap:

- Number — 6
- Manufacturer — Locke Insulator Corp.
- Type — 36-inch-diameter ring of 1-inch steel pipe, for mounting directly on caps and base of insulation stacks, complete with adjustable bottom shield between 35 inches and 45 inches in steps of 1 inch.
- Rating — 161 kilovolts

1944 SWITCHYARD EXTENSION

Autotransformer Bank

- Number — 3
- Manufacturer — General Electric Co.
- Type — Outdoor, oil-insulated, water-cooled
- Rating — Single [illegible] volt-amperes, on the 161-/112.7-kilovolt windings and 1,333 [illegible] on the 14.17-kilovolt tertiary winding, 60 cycles, 55-degree centigrade rise
- Connections — High side wye with grounded neutral and the tertiary winding delta
- Polarity — Subtractive
- Impedance:
  - 161,000 Y to 112,700 Y volts at 9,500 kilovolt-amperes — 4.95 percent
  - 161,000 Y to 14,170 volts at 1,333 kilovolt-amperes — 2.10 percent
  - 112,700 Y to 14,170 volts at 1,333 kilovolt-amperes — 2.44 percent
- Regulation:
  - 161,000 Y to 112,700 Y volts:
    - 100 percent power factor — 0.48 percent
    - 90 percent power factor — 2.57 percent
    - 80 percent power factor — 3.31 percent
- Exciting current:
  - 161,000 Y to 112,700 Y volts — 2.08 percent
- Losses:
  - 161,000 Y to 112,700 Y volts, 9,500 kilovolt-amperes:
    - Core — 28,950 watts
    - Load — 29,600 watts
    - Total — 58,550 watts
  - 161,000 Y to 14,170 volts, 1,333 kilovolt-amperes:
    - Core — 28,950 watts
    - Load — 1,800 watts
    - Total — 30,750 watts
  - 112,700 Y to 14,170 volts, 1,333 kilovolt-amperes:
    - Core — 28,950 watts
    - Load — 3,100 watts
    - Total — 32,050 watts
- Segregated weights:
  - Core and coil — 33,500 pounds
  - Tank and fittings — 29,500 pounds
  - Oil — 52,000 pounds
  - Total — 115,000 pounds
- Dimensions:
  - Projected floor space — 103½ by 168⅛ inches
  - Height over tank — 167¼ inches
  - Height over-all — 259½ inches
  - Untanking height — 302¾ inches

Oil Circuit Breakers

161-kilovolt oil circuit breakers:

- Number — 1
- Manufacturer — General Electric Co.
- Type — 3-pole, electric motor-operated, 8-cycle opening, outdoor, type FHKO-39-72B-F4.
- Rating:
  - Rated voltage — 161 kilovolts
  - Rated continuous current — 600 amperes
  - Rated frequency — 60 cycles
  - Interrupting capacity — 1,500,000 kilovolt-amperes

Potential coordination gap—Continued
110-kilovolt oil circuit breakers:
Number ---------- 1
Manufacturer---------- Westinghouse Electric & Manufacturing Co.
Type------ 3-pole, electric solenoid-operated, outdoor, single-shot reclosing, 8-cycle opening, type G22-P.
Rating:
Rated voltage---------- 110 kilovolts
Rated continuous current---------- 600 amperes
Rated frequency---------- 60 cycles
Interrupting capacity---------- 750,000 kilovolt-amperes
15-kilovolt oil circuit breakers:
Number ---------- 2
Manufacturer---------- General Electric Co.
Type------ 3-pole, solenoid-operated, outdoor, standard 3-shot reclosing, frame-mounted, type FLO-2.
Rating:
Rated voltage---------- 15 kilovolts
Rated continuous current---------- 600 amperes
Rated frequency---------- 60 cycles
Interrupting capacity---------- 250,000 kilovolt-amperes

Lightning Arresters

115-kilovolt arrester:
Number ---------- 1
Manufacturer---------- General Electric Co.
Type---------- 3-pole, station type
Rating---------- 115 kilovolts, line-to-line
Maximum voltage, line-to-ground---------- 103 kilovolts
Reseal voltage, line-to-ground---------- 103 kilovolts
161-kilovolt arrester:
Number ---------- 1
Manufacturer---------- Westinghouse Electric & Manufacturing Co.
Type---------- 3-pole, station type
Rating---------- 161 kilovolts, line-to-line
Maximum voltage, line-to-ground---------- 145 kilovolts
Reseal voltage, line-to-ground---------- 145 kilovolts
13.8-kilovolt arrester:
Number ---------- 1
Manufacturer---------- Westinghouse Electric & Manufacturing Co.
Type---------- 3-pole, station type
Rating---------- 13.8 kilovolts, line-to-line
Maximum voltage, line-to-ground---------- 12 kilovolts
Reseal voltage, line-to-ground---------- 12 kilovolts

Voltage Regulator

Number ---------- 1
Manufacturer---------- General Electric Co.
Type----------Outdoor, self-cooled, step type, oil-insulated
Rating------ 3-phase, 300 kilovolt-amperes, 60 cycles, 13,800 volts, 10 percent plus or minus regulation in 16 1¼ percent steps.
Segregated weights:
Regulator with oil---------- 11,750 pounds
Liquid ---------- 4,150 pounds
Total---------- 11,750 pounds
Dimensions:
Projected floor space---------- 71 by 75 inches
Height over case---------- 92 inches
Height over all---------- 102 inches

Emergency Station Service and Grounding Transformer

Number ---------- 1
Manufacturer---------- Moloney Electric Co.
Type---------- Outdoor, oil-immersed, self-cooled

Potential coordination gap—Continued

Rating______ 1,500 kilovolt-amperes, 3-phase, 13,200–480 volts, 60 cycles, 55-degree rise.

Connections__________ High side wye with grounded neutral, low side delta

Taps____________ 2 2½ percent above and below 13,200 volts, full capacity

Manufacturer's test data at 75° C. rated voltage, and frequency, average values:

Impedance	4.44 percent
Reactance	4.36 percent
Exciting current	1.57 percent
No-load losses	4,109 watts
Total losses	16,249 watts

Regulation:

Percent power factor	100	80
Percent regulation	0.91	3.35

Efficiency at 100 percent power factor:

Percent load	100	75	50	25
Percent efficiency	98.92	99.03	99.05	98.72

Segregated weights:

Core and coils	8,025 pounds
Tanks and fittings	4,800 pounds
Oil (725 gallons)	5,450 pounds
Total	18,275 pounds

Dimensions:

Projected floor space	70 by 106 inches
Height over tank	101¾ inches
Height over all	117¼ inches

Disconnecting Switches

161-kilovolt switches:

Number______________________ 1 manually gang-operated, 600 amperes; 1 motor-operated, 600 amperes.

Manufacturer________________________Electric Power Equipment Co.

Type______ 3-pole, single-throw, horizontal, underhung, outdoor type

110-kilovolt switches:

Number ______ 1 manually gang-operated, 600 amperes with grounding blade; 1 manually gang-operated, 600 amperes.

Manufacturer______________________________ Delta Star Electric Co.

Type___________ 3-pole, single-throw, vertical mounting, outdoor type

15-kilovolt switches:

Number ______ 12 hook-stick-operated, 600 amperes; 1 manually gang-operated, 600 amperes.

Manufacturer______________ Memco Engineering & Manufacturing Co.

Type_________ Single-pole and 3-pole, vertical mounting, outdoor type

15-kilovolt switches:

Number______________________ 3 manually gang-operated, 600 amperes

Manufacturer________________________ Southern States Equipment Co.

Type_____________ 3-pole, single-throw, vertical mounting, outdoor type

Line Traps

Number____ 2

Manufacturer___________________________________ General Electric Co.

Type_______ 2 single-frequency, 400 amperes. All have a 50- to 150-kilocycle tuning range.

Potential Coordination Gap

Number____ 3

Manufacturer___________________________________ Locke Insulator Corp.

Type______ 36-inch-diameter ring of 1-inch steel pipe, for mounting direct on cap and base of insulator stack, complete with adjustable bottom shield between 23 and 32 inches in steps of 1 inch

Rating____ 115 kilovolts

INSULATORS

161-kilovolt service:	
Rating and type	38-kilovolt, pedestal type
Number of units per stack	4
Manufacturer	Locke Insulator Corp.
Dry flash-over per stack	485 kilovolts
Wet flash-over per stack	380 kilovolts
Leakage distance per stack	132 inches
Cantilever strength, upright	1,200 pounds
15-kilovolt service:	
Rating and type	15-kilovot, pedestal type
Manufacturer	Ohio Brass Co.
Dry flash-over	85 kilovolts
Wet flash-over	50 kilovolts
Leakage distance	11⅝ inches
Cantilever strength, upright	1,500 pounds
161-kilovolt service:	
Rating and type	15-kilovolt, suspension type
Number of units per string	11
Manufacturer	Locke Insulator Corp.
Dry flash-over	635 kilovolts
Wet flash-over	465 kilovolts
Mechanical strength	15,000 pounds

Appendix B

REPORTS OF CONSULTING ENGINEERS AND GEOLOGISTS

This appendix contains the joint recommendations and approvals following studies by the Tennessee Valley Authority Board of Consultants. In addition, individual reports were also prepared by consultants on research and other work ordinarily done by regular staff members of the TVA, but this appendix has been limited to the reports of the consultants acting as a board.

Geological and Foundation Conditions

February 27, 1942

The undersigned consultants assembled at Knoxville on Tuesday, February 24, 1942, and after having the general purpose and scope of the meeting stated by Theodore B. Parker, Chief Engineer, heard progress reports from members of the chief engineer's staff on the work to date on foundation explorations, concrete aggregate quarry investigations, and on cofferdam and construction plant layout for the Douglas Dam.

Since the weather was unfavorable for a field inspection by automobiles, some time was spent on a study of TVA Report No. O–134–6, which had been furnished the consultants previously, and in discussing with members of the Chief Engineer's staff various features of the three projects under consideration. The party left Knoxville at 2:55 p. m. via Southern Railway for Johnson City, Tenn., and spent the night there.

On Wednesday, accompanied by the chief engineer and members of his staff, the consultants continued by automobile and inspected the dam sites and borrow areas of both the Watauga project and the South Holston project, and examined the cores from one hole at the Watauga Dam site and from a large number of holes at the South Holston Dam site. On the return trip to Knoxville the consultants stopped at the Douglas Dam site and saw the work in progress there, including the earth and rock excavation into the right abutment, and examined a large number of cores.

On Thursday and Friday the consultants resumed discussion and heard more detailed reports on the geological and foundation conditions at the Douglas Dam and on the borrow pit materials and embankment design methods on the Watauga and South Holston Dams.

The consultants' discussions and answers to the questions furnished for their consideration follow in the order of the listing in TVA Report No. O–134–6 mentioned above.

Question 1: Does the proposed site provide in general a safe and dependable foundation?

In arriving at an understanding of this site the members of the consulting board have had not only the exploratory data gathered from borings and field studies made by the regular staff but also the advantage of a field inspection of the ground and boring samples under the guidance of the men in charge. In this manner the consultants have satisfied themselves of the local geological conditions, which they are convinced are sufficiently well determined to warrant a favorable answer to this question.

The rock floor both beneath the principal section under the river and in the immediate abutments is a gently dipping massive Knox dolomite, a well-known formation of usually satisfactory character, affected in this instance chiefly by the normal processes of weathering. This has developed a thin mantle of residuary soil, over a pinnacled rock surface, and occasional solution cavities and

decay effects, which for the most part start at the surface of the floor and extend downward chiefly along bedding planes to no great depth. A geological section, therefore, shows a saw-tooth sort of profile. These effects on the main foundation area, as indicated directly by borings data, do not interfere greatly with the general stability or average strength of the foundation; but they do indicate the necessity of variable amounts of excavation to remove the most affected uppermost portion down to sound rock for seating the dam. Despite variations of rock character and other minor features, no unusual or dangerous conditions exist, and whatever weaknesses of smaller size and deeper extension remain can without doubt be successfully treated.

In reaching this conclusion we do not overlook the fact that somewhat greater complexity is evident at each end of the dam. Out on the right abutment there is evidence in the so-called "breathing" of certain holes that cavernous conditions are more pronounced there, but it is beyond the main dam structure and introduces no suspicion of the stability of the formation. The water table also is low and may indicate greater solution and permeability than elsewhere and may require more extensive treatment. These conditions, of course, deserve and will be given further field study.

Out on the left abutment two structural changes have been encountered—first, a deformed condition shown by disturbed bedding in a zone that is believed by the local geologists to indicate faulting; and next, an abrupt change in rock formation from the dolomite to a series of shales. This contact is marked also by displacement. The formation from this point on is made up of different varieties of shale members which are of practical significance chiefly at the saddles along the west boundary of the reservoir.

It is appreciated by all concerned that these two features may have greater practical importance than has appeared thus far and for this reason are to be investigated further. There is no reason, however, to regard their present problematic character with suspicion as affecting the conclusions already expressed that the site as a whole is acceptable geologically and that a safe and dependable structure such as is proposed can be built on this site.

Question 2: Will a concrete dam constructed in accordance with present design be stable?

In general, the proposed design for Douglas is planned to be similar to the design for the concrete portion of the Cherokee Dam.

The maximum height of Douglas Dam above river bed will be about 155 feet compared with 180 feet for Cherokee, and the spillway will be longer. The spillway gates will be duplicates of those at Cherokee, but to accommodate the larger drainage area there will be eleven 32- by 40-foot taintor gates at Douglas as compared to nine gates of the same size at Cherokee.

It is planned to provide a grout curtain under the heel of the dam with a line of foundation drain holes a short distance downstream from this curtain.

We conclude that the Douglas concrete dam constructed in accordance with the planned design will be stable.

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O. N. Floyd,
L. C. Glenn,
W. H. McAlpine,
W. F. Prouty,
W. F. Uhl.

Foundation Treatment Program

June 18, 1942

The undersigned consultants assembled at Knoxville on Monday, June 15, 1942, and after having the general purpose and scope of the meeting stated by the chief engineer we were given copies of TVA Report No. 0–134–7, which contained progress and other information regarding the projects under consideration.

After a brief discussion, we, accompanied by the chief engineer and members of his staff, left for the Douglas Dam site by automobile. We made an inspection of the work in progress, giving speci[illegible] ndation conditions at the abutments and the unwatered [illegible] d. We also visited saddle dam No. 1 and the drainage [illegible] er construction just downstream from the saddle dam. [illegible] itself is well along toward completion.

We returned to Knoxville during the afternoon and discussed the work in progress at Douglas and the construction and foundation treatment program outlined in TVA Report No. 0–134–7.

The chief engineer asked us to answer the following question:

Question 1: Is the foundation treatment program, outlined in this report and now being followed, satisfactory?

Subsurface conditions.—Generally, the exploration and excavation completed to date at the site of the concrete dam indicate that, in the the river channel, the top 20 to 40 feet of rock is so badly weathered as to require removal in order to reach an adequate foundation. The strike of the steeply dipping bedding planes is closely parallel to the river flow and much of the weathering is along the bedding planes. As a result the top of the sound rock has a saw-tooth profile. Below the badly weathered rock, which is to be taken out, the rock appears to be fairly free from large cavities or extensive weathered areas.

In the right abutment from a point beyond the end of the concrete dam and cut-off to block 5 a large ramifying cavity has been found, and explored, about 40 feet below the bottom of the foundation excavation.

The left abutment is sound rock as far as excavated for the river diversion channel but just south of this excavated face at station 19+00, or at block 33, a deep weathered zone or fault exists extending down to at least elevation 810 or about 60 feet below the river bed. Immediately south of this an open cavity of considerable extent has been found.

Proposed treatment.—In the right abutment the portions of the cavern underneath the concrete dam and the concrete cut-off wall have been mined out from 36-inch holes and filled with concrete. This is to be followed by pressure grouting.

Under the concrete dam and spillway, consolidation grouting will be done on a pattern of holes spaced 20 feet center to center each way drilled from 30 to 40 feet deep below the final foundation excavation. Check holes will be drilled in between these as the take of grout indicates the need for additional treatment.

The grout curtain cut-off under the heel of the dam will first be grouted through holes 40 feet deep with initial spacing of 24 feet reduced in stages to a maximum of 6 feet. This curtain will then be extended down to a depth of 100 feet with holes spaced 18 feet apart. A few test holes as deep as 200 feet will be drilled and grouted to determine if the grout curtain needs to be extended deeper than 100 feet. Insofar as practicable, it is planned to place the grout curtain to the 40-foot depth in advance of placing the concrete. The deeper curtain grouting is to be done after the concrete in the region of the grouting is at least 40 feet high and generally the drilling and grouting will be done through the sloping concrete heel.

South of the sound rock bluff at the diversion channel in the left abutment full plans for treatment have not been developed, but generally the weathered rock and caverns will be excavated or mined out, filled with concrete under the dam and cut-off and later followed with pressure grouting.

At saddle dam No. 1, a cut-off has been made along the center line into the shale as deep as practicable without blasting, and grouting along this line has been done through holes 25 feet apart and extending down to about river elevation. The grout take in a few of these holes was considerable, but the core loss was negligible with no indication of cavities.

The left ridge between saddle dams will be tested with holes and grouting where the horizontal distance through the ridge is less than 500 feet at the reservoir water level.

The general foundation treatment plan for Douglas Dam appears to give a minimum coverage sufficient to contact the typical weathered areas and the present practice of developing, by additional drilling and grouting other areas requiring more extensive treatment, should result in a satisfactory foundation and cut-off.

It may be questioned whether the maximum spacing of 18 feet as proposed for the deep high-pressure holes in the grout curtain under the spillway will provide a sufficiently tight curtain. We recommend that the effectiveness of the 18-foot spacing be tested by intermediate holes at various points in the grout curtain.

On the left abutment where deep weathering has been revealed at about block 33 (18+75 to 19+25) deeper surface excavation will be necessary before the extent of the weathering and suspected probable faulting can be determined. If a narrow block has been dropped between two parallel fault planes, forming a graben, crushing and weathering may have so cooperated as to require deep excavation and extensive cut-off treatment, the plans for which may need to be modified as the excavation progresses.

The reason for the unexpectedly large grout take in the compact black shales beneath the saddle dam in the left abutment ridge is not apparent. It is not, however, believed that these shales contain cavities of any serious importance.

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FOUNDATION CONDITIONS AND FOUNDATION TREATMENT

October 8, 1942

On Wednesday morning, October 7, the undersigned consultants, accompanied by the chief engineer and members of his staff, made an inspection of the work in progress at Douglas Dam, giving special attention to foundation conditions and foundation treatment for the permanent structures and the proposed treatment of the cavity in the south abutment and the reservoir rim beyond this cavity.

This inspection was followed by a conference in the field office where the foundation treatment already carried out was explained and the treatment of the south abutment was discussed.

We returned to Knoxville in the afternoon and discussed the work in progress and reviewed the data on this project contained in TVA Report No. 0–134–8.

The several questions presented in the office memorandum as related to the Douglas project are essentially of engineering character, but in each case take on their special significance from the physical condition of the foundation rock. It seems advisable, therefore, to introduce the discussion of those matters with a brief review of the local geological features as now developed.

The foundation.—Continued exploratory investigations, together with extensive excavation and other steps related to construction, have greatly clarified the picture of local rock structure, due to regional deformation, and also its condition, due chiefly to solution and weathering. At this stage, therefore, it is believed that virtually all features of direct practical significance either have been fully proven or can be reasonably inferred from this well-executed work.

As was pointed out in the June memorandum of this Board and as excavation connected with construction has fully proven, the major rock weaknesses and associated circulation of ground water beneath the river channel are largely limited to an upper zone. At deeper levels the natural rock formation is essentially sound with only occasional and minor features of this character. It has been practicable, therefore, as expected, to continue construction development by removing the floor rock beneath the dam and powerhouse to a level that is of satisfactory strength and stability to carry these structures. This leaves to grouting treatment the remaining deeper seams and other imperfections of the rock floor, such as bedding planes, joints, deformation fractures, and associated solution effects. There is no doubt but that treatment can be devised to accomplish both major objectives—that of consolidation and of ground-water control in the floor beneath. Successful foundation, therefore, is assured. Construction is adjusted to these natural conditions, and no other elements of weakness or troublesome afterbehavior have been discovered.

Left abutment.—As was known from earlier exploratory work, the fine massive wall of almost perfectly bedded dolomitic rock that forms the left abutment is not continuous in that condition. Within a short distance deformation structures in the form of sheeted rock, gapping joints, slips, fault zones, and at least one displaced graben-like fault block are all exposed in the excavations now in progress. And in one case, following a strong bedding structure doubtless disturbed somewhat by deformation, a cavernous condition and associated solution effects with residuary alternation products show marked development and is being mined out along the line of the dam for cut-off purposes. It is known, however, that its lower southerly extension closes down to small dimensions in that direction. This structure which owes its present importance to its cavernous and softened condition is especially strongly developed near the fault zones of the abutment already noted. One cross channel encountered in tunneling near that end was found to be essentially clear of residuary debris indicating,

it is believed, that ground water must have moved parallel to the course of the rim along this channel rather freely. At the crossing of this channel with the course of the tunnel a sizable cavernous enlargement was encountered. This, however, is the only important open cross structure thus far discovered.

It is evident that these conditions, despite the depth reached and despite the masses of sound rock both above and below the seam, will require some kind of special treatment designed to check the flow of water which it appears will have full pressure of the reservoir back of it. Although other structures of the immediate vicinity, such as the fault zone, are much larger geological features, the one that seems to present the more difficult treatment problems is this cavernous bedding seam of the left abutment.

South rim saddles.—Several depressions requiring low dams along the narrow rim, closing the reservoir beyond the left abutment, continue to attract exploratory attention. No. 1, nearest the river, has been filled and treated already and is believed to have met the local condition successfully.

The gaps on this side of the reservoir are all situated on the shale formation and on that account do not present the troublesome solution features characterizing the carbonate rocks. To that extent, therefore, all of these sites ought to offer comparatively satisfactory structural underground conditions. Even the exposed ledges are not as deeply affected as the other formations, although weathering has attacked them all and deformation has accomplished much internal readjustment. Borings where made have shown in general sound rock.

On the whole the geological conditions are favorable. Therefore, ordinary construction precautions and treatment ought to prove effective in this whole series, and some of the sites may not require much special attention.

The north rim.—Up-to-date returns from exploration show that the rock floor beyond the end of the mined-out cavity under that end of the dam develops a depression and that a possible sink cavern may have been encountered. Also the three borings nearest the end of the dam seem to show solution effects in line, suggesting that they may belong to a bedding plane dipping toward the river at a depth of 40 feet or so below pool level.

These features are all consistent with the known structure of the rock formation on that side. No especially disturbing features seem to be indicated by the explorations thus far, but it appears that those nearest to the dam warrant treatment designed to close such channels of circulation as may follow them.

On the whole, the north rim does not appear to present large difficulty but exploratory work should be continued.

Question 1: Are the plans and proposed methods for installing a concrete barrier in the left abutment cavity to the approximate station 23+75 and for grouting that cavity beyond that station adequate?

This cavity begins at the end of the open excavation at approximately station 20+00. It extends down the dip and has been mined out for a distance of about 280 feet. The height of the cavity runs from 3 feet near the entrance to 20 feet maximum at station 21+20, with most of it about 7 feet high between bedding joints. The floor generally is a smooth bedding plane, but the roof at several places is irregular from weathering. The average width of the channel mined out is about 20 feet but wide enough at all points to build the proposed concrete seal with work room on each side for stripping forms, calking between the roof and the top edges of the concrete plug and performing the necessary grouting operations between the roof and the concrete plug and observations for grout leaks.

No attempt was made to clean out the cavity for its full width, which is doubtless most too great for such treatment. Near station 21+20 a rather large cross cavity was found, approximately along the strike and open enough to walk in for more than 100 feet on each side of the main cavern. A second similar cavern was found at station 23+40 except it is smaller and largely filled with clay and was wet enough to require pumping. At other points where the sides of the main cavern were uncovered, there appeared to be smaller strike or dip joint channels leading off.

The concrete seal or wall is to be keyed into the rock floor and designed so that the shear on the base does not exceed 30 pounds per square inch with full hydrostatic head from the reservoir against the seal. After the concrete has had time to cool and shrink, the joint between the roof and the top of the concrete will be grouted. Suitable grout pipe, inlets, V-troughs, etc., will be installed as the concrete is placed, and the outer edges of this contact joint will be caulked after the concrete has set.

After the concrete seal has been placed and the top contact joint grouted we recommend that the remaining unfilled cavity immediately upstream from the concrete seal be filled with clay through holes from the ground surface.

The diamond-drill holes beyond station 23+75 indicate that this cavern pinches down to less than a foot in height and after exploring this area further with diamond-drill holes, it should be washed and grouted with cement and clay grout.

It is our opinion that the treatment briefly described above and outlined more in detail in the TVA Report No. 0-134-8 of October 5, 1942, and on drawing 21DS 203-1 in that report will be adequate.

We recommend that concrete wings be provided on each side of the main concrete seal near its south end to avoid the loss of grout up along the sides of this concrete seal while grouting from the seal on south and also to prevent any seepage that may reach the upstream face of the concrete seal from finding a short passage around the south end of the seal. These wings should be right-angle extensions of the main seal into sound rock on each side of the main cavern.

Question 2: Are the methods outlined for foundation treatment of the foundation for the permanent structures satisfactory?

Foundation treatment for the permanent structures includes removal of the broken, dissolved, and badly weathered rock and the treatment of the more suitable rock by consolidation and curtain grouting.

As far as the main river structure which has so far been largely built is concerned, the trea[illegible] planned and outlined in our report of June 18, 1942, has been [illegible] difficulty, except for the excessive inflow of water into the cofferdam area. This includes the north abutment, the intake and powerhouse, and a short section of the spillway (blocks 1 to 19, inclusive).

We consider the methods outlined for foundation treatment and now in use entirely satisfactory.

Question 3: Is the outlined program for the exploration and grouting for the south side saddle dams and reservoir rim sufficient? Will a similar program be sufficient for the north reservoir rim adjacent to the dam for a distance of 500 feet and up to elevation 1080?

It is planned to drill and grout the south reservoir rim between the end of the dam and saddle dam No. 1, also the shale rim to the south where the rim thickness at reservoir level is 300 feet or less.

First-stage grouting with cement at 100-foot centers with intermediate grouting at 50-foot centers is planned and is now in progress. This grouting program is considered to be sufficient for the south rim, unless further drilling indicates the need for closer spacing.

Exploratory drilling so far carried out in the north rim of the reservoir beyond the north abutment core wall has disclosed a number of cavities below reservoir level in the first 300 to 400 feet from the core wall. The bore holes indicate cavities from a fraction of a foot in depth to cavities from 3 to 13 feet deep.

Additional explorations should be made to determine the extent of these cavities so that a method of treatment may be worked out.

The north rim adjacent to the abutment rises rapidly making treatment of these cavities, which are 100 feet or more below the surface, very difficult except by drilling and grouting.

If the cavities are found by additional explorations to be limited in extent, drilling and grouting as proposed for the south rim may prove satisfactory. However, closer spacing of grout holes will undoubtedly be necessary. If the disclosed cavities are found to be extensive, mining methods through deep calyx drill holes may have to be adopted.

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FOUNDATION TREATMENT AND LEAKAGE CONDITIONS

July 22, 1943

Copies of TVA Report No. 0–134–10 were furnished the consultants upon their arrival Monday morning, July 19, which contains a review and records of foundation treatment and amounts of leakage through the main dam and saddle dams as well as data concerning reservoir filling, starting of the plant, and present progress on the erection of the second unit.

On Monday afternoon, July 19, the consultants, accompanied by C. E. Blee, Chief Engineer, and members of his staff, visited Douglas Dam and made an inspection of the completed dam, power plant, and the saddle dams, including the backwater protection work at Dandridge.

The chief engineer asked the consultants the following question:

"Do the records of foundation treatment and amounts of leakage through the main dam and saddle dams, together with your general inspection of the structures, indicate that Douglas Dam, as finally completed, has been satisfactorily constructed?"

Since the consultants' last visit all major construction work has been completed and the reservoir has been filled to about elevation 998 (full reservoir elevation is 1002).

The report above referred to gives at some length the details of foundation excavation and treatment adopted to meet conditions encountered in the badly weathered rock underneath the concrete dam, the mud-filled solution cavities and cave-like channel on the south abutment, the solution encountered on the north abutment and rim, and the leakage conditions in the several saddle dam areas.

The consultants were impressed with the apparently small amount of leakage, the excellent appearance of the various structures, and the fact that the dam was completed, with all of its difficult foundation conditions, on schedule time.

From the details of the treatment adopted for all of these problems as given in the report and from the visual inspection of the structures made on the ground by the Board, we believe that Douglas Dam has been satisfactorily constructed. The backwater protection work at Dandridge appears adequate to solve the problem of providing the necessary drainage and has certainly greatly improved the appearance of that portion of the town.

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Appendix C

SPECIAL STUDIES

The TVA conducted special studies and tests in connection with the design and construction of the Douglas project. Hydraulic model studies were made in order to develop and verify the design of the spillway apron and water passages. Schedules were determined for spillway and sluice operation causing the least possible amount of erosion below the apron.

HYDRAULIC MODEL TESTS

The designs of the principal features of all major projects constructed by the TVA have been verified prior to construction by accurate tests on small scale models. These models have facilitated the development of structures for which mathematical analysis could not be accomplished accurately. The tests often indicate revisions in design that result in more efficient performance or more economical construction. All model tests for the Douglas project were made in the hydraulic laboratory at Norris, Tenn.

Development of spillway apron

The design for Douglas Dam utilized, insofar as possible, the previously tested design for Cherokee Dam. The original plan was to use the Cherokee apron and sluice design, and the first tests were made on this basis. As the rock excavation for the apron progressed it became evident that changes in the apron shape would be necessary and additional tests were made. No changes were found necessary in the sluice design.

Description of model.—The first tests of the apron design and of the operation of the project as a whole were studied on a 1:70 scale model which included the spillway, the powerhouse, and 3,000 feet of topography below the dam. The 11 spillway bays were built and fitted with crest gates designed to operate uniformly.

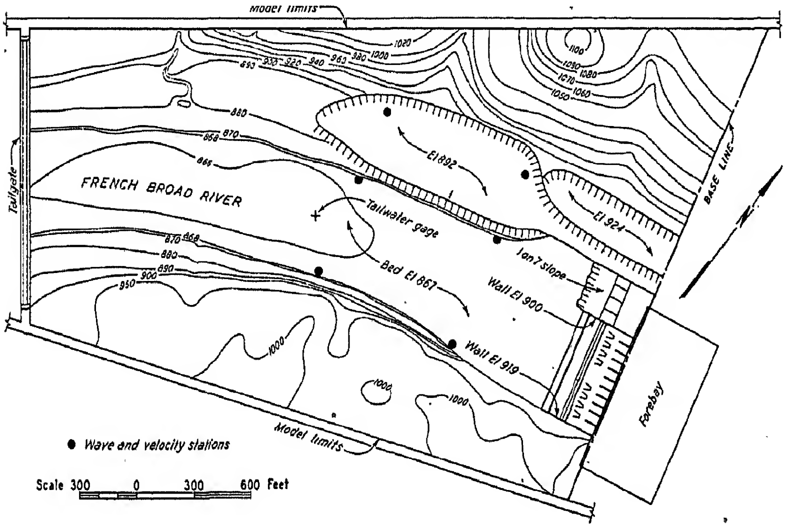

FIGURE 151.—*Layout of original 1:70 scale model, using Cherokee-type apron.*

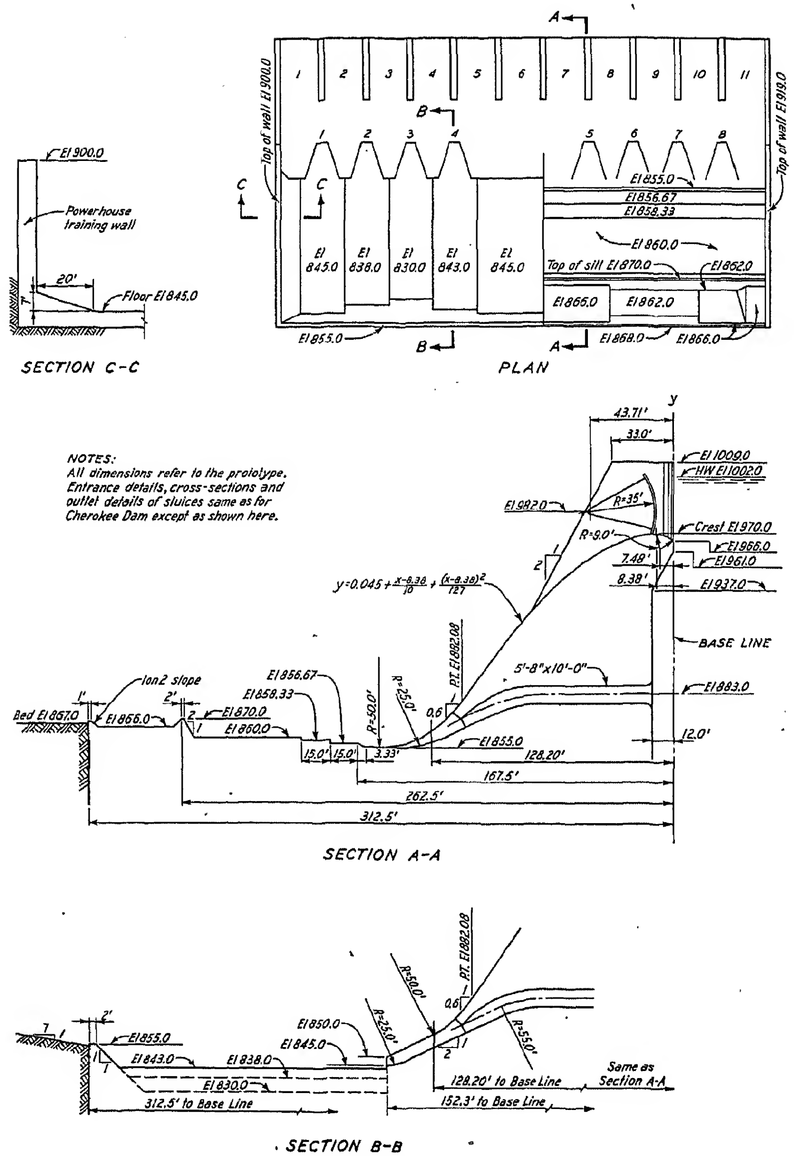

FIGURE 152.—*Model layout and details adopted.*

Eight sluices were placed in the spillway section. The model for the final tests was similar, except that the length of the river reach below the dam was reduced to about 1,300 feet, and the necessary changes in the apron design were made to correspond to the data received from the field. Figure 151 shows the layout for the early model and figure 152 the layout for the later model. The experi-

mental data on erosion below the apron were obtained by making surveys over the movable bed and by photographs and visual observations.

The model tests were conducted with the aim of providing good operating conditions with a minimum of erosion for all discharges up to 100,000 cubic feet per second. It was also necessary that the safety of the dam be assured for higher discharges. It was considered that some damage might be allowed to occur at higher discharges because of their relative infrequency. The probable maximum discharge of the French Broad River at the dam site was estimated at 330,000 cubic feet per second. It was assumed that all prototype spillway gates would be operated uniformly. Accordingly, tests were made for only one tailwater elevation for each spillway gate opening.

Tests on Cherokee-type apron.—The original model utilized the Cherokee apron design and left bank training wall. Tests were made to determine the best design for the powerhouse training wall and the necessity for changes in the apron to reduce erosion below the sill.

A test utilizing the Cherokee powerhouse training wall design with a spillway discharge of 300,000 cubic feet per second showed heavy erosion on the right bank side directly downstream from the training wall. Two schemes were tried in order to obtain a reduction in this erosion.

In the first scheme, the apron adjacent to the training wall was extended out to the end of the wall. Two types of extension were tested: one with a sill running at an angle of 45 degrees from the end of the training wall back to the original sill; the other with a sill running parallel to the original sill for 50 feet from the end of the wall and then angling back at 45 degrees to the original sill. In figure 153, aprons C and D illustrate the first type of extension and aprons E and F the second.

In the second scheme the length and height of the training wall were reduced. Best results from the tests on both schemes were obtained with a wall at elevation 900, cut off square with the downstream end of the apron and with no apron extensions. This design is shown as apron H in figure 153. For a discharge of 300,000 cubic feet per second, the erosion at the structure was smaller and the over-all erosion pattern was less severe than for any of the other aprons tested. There was no erosion with this apron for a spillway discharge of 100,000 cubic feet per second.

Tests on revised apron

As the rock excavation for the apron progressed in the field it became evident that changes in the apron shape would be necessary to fit existing foundation conditions at the dam. The situation on the right side of the river made it essential that this portion of the apron be lowered considerably, requiring also a change in the shape of the bucket near the sluice outlets. Construction, design, and model testing were in progress simultaneously and changes were incorporated in the model as rapidly as data were received from the field. Consequently, many tests were made on aprons which, as a result of further rock excavations, were found to be no longer feasible.

The apron finally adopted is shown in figure 152, together with a layout of the model. The left portion was the same as the originally tested Cherokee-type apron with some minor revisions. Major changes were made on the right portion of the apron. It was also necessary to revise the bucket and the downstream portion of the sluice outlets on the right side of the apron and the footing for the powerhouse training wall.

Erosion at ends of spillway

This description of the erosion tests will be limited to those for the finally adopted apron. For these tests the river bed below the left portion of the apron was molded level 1 foot below the top of the sill. Below the right portion the bed was molded to a 1 on 7 slope from 1 foot below the top of the sill to river-bed elevation.

The adopted apron gave satisfactory operation at all discharges for sluices and spillway. With all sluices operating there was very little erosion and the flow conditions on the apron were satisfactory. With all spillway gates open uniformly the operation of the apron was very uniform, and there was only a negligible amount of erosion for discharges up to 100,000 cubic feet per second. For a discharge of 120,000 cubic feet per second over the spillway and 30,000 cubic feet per second through the sluices a moderate amount of erosion occurred quite generally over the river bed below the end sill of the apron, reaching

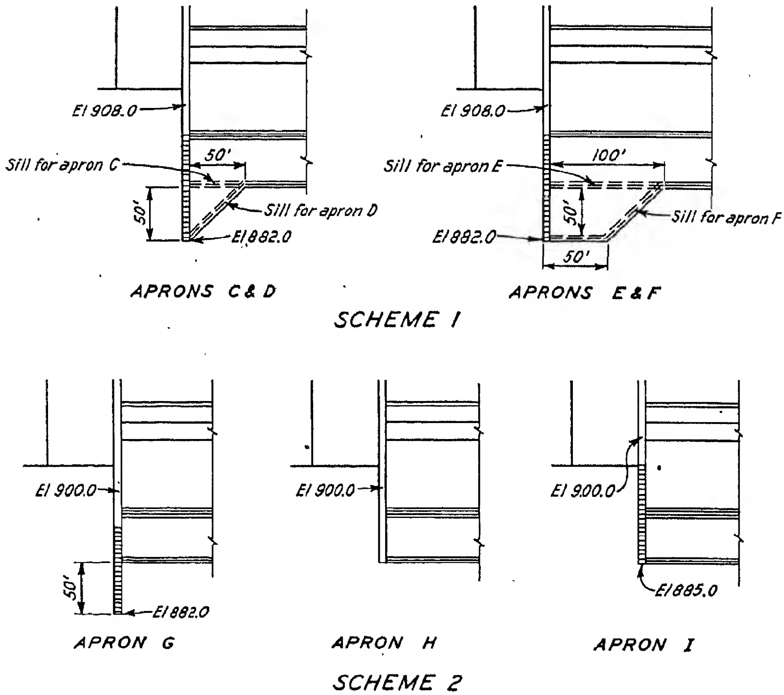

FIGURE 153.—*Right training wall and apron arrangements tested.*

a minimum elevation of 843 about 25 feet downstream from the sill in the vicinity of the powerhouse training wall. This erosion was not considered excessive.

For the maximum discharge of 300,000 cubic feet per second over the spillway plus 30,000 cubic feet per second through the sluices the erosion was quite general, reaching a minimum elevation of 830 at the corner of the powerhouse training wall. A deposit of eroded material as much as 12 feet deep covered the left half of the apron downstream from the main sill.

For structural reasons it was found necessary to place a footing under the powerhouse retaining wall, extending out onto a portion of the apron at elevation 845. Tests showed that this footing had no measurable effect on the erosion. Figures 154 and 155 show the erosion observed with discharges of 150,000 and 330,000 cubic feet per second, respectively.

Water-surface profiles

A water-surface profile was determined along the powerhouse training wall for a combined sluice and spillway discharge of 150,000 cubic feet per second. Profiles determined in the original tests for design of the left training wall were applicable since only minor changes were made on the left side of the apron. For a total discharge of 330,000 cubic feet per second, an unbalanced load on the powerhouse training wall was caused by the water surface on the apron being depressed considerably below tailwater elevation due to the hydraulic jump on the apron.

Wave heights

Turbulent operation on the apron produces waves in the river channel below. Knowledge of the height and frequency of these waves is useful in the design of riprap protection for the river banks. Wave heights were measured on the model by placing a small staff gage at the desired locations and photographing

the motion of the water surface with a motion-picture camera. The film was examined, frame by frame, and water-surface elevations were plotted against time in terms of prototype dimensions. The model layout in figure 151 shows the location of the wave stations.

Gate-operating restrictions

Random or unsymmetrical operation of the surface or spillway gates may result in a concentration of flow and serious scour. Tests were made on the model to determine the proper sequence of operation for both the spillway and the sluice gates.

The sluice gates were numbered from the powerhouse and were assumed to be operated either wide open or closed. The spillway gates were numbered similarly and were assumed to be operated uniformly. The sluice gates were found to give best flow conditions if they were opened in the order 7, 2, 4, 5, 8, 1, 3, and

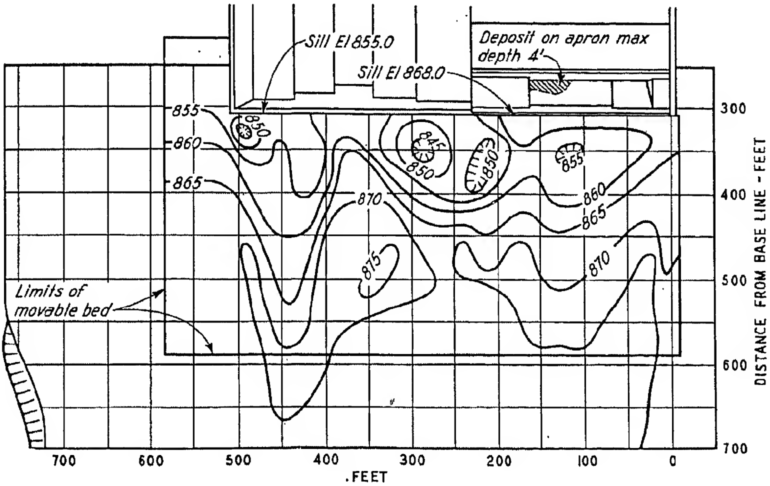

FIGURE 154.—*Erosion below spillway for discharge of 150,000 cubic feet per second.*

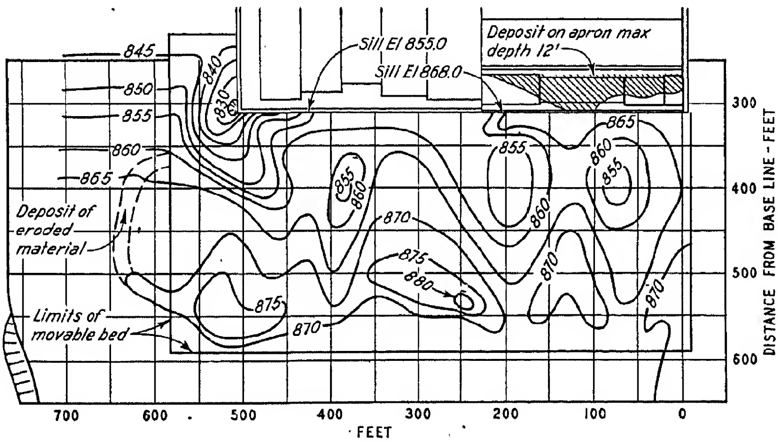

FIGURE 155.—*Erosion below spillway for discharge of 330,000 cubic feet per second.*

6. This order reduces the flow across the apron from the high to the low side and prevents the formation of an eddy in the center of the apron. The best opening sequence for the spillway gates was 9, 3, 5, 7, 11, 1, 10, 2, 8, 4, and 6. It was assumed that the maximum difference between gate openings would be limited to 4 feet.

UPLIFT AND DRAINAGE

Certain observations on the performance of Douglas Dam have been conducted at regular intervals since the construction was completed and the reservoir filled in 1943. These observations have been less comprehensive than those made on other structures of the TVA, but since they are now available for a period of 5 years, it appears worth while to present a statement of results. These results are summarized in the following paragraphs and illustrated in figures 156 and 157.

Foundation uplift

When the dam was constructed, the necessary arrangements were made for measuring the intensity of uplift in the foundation contact area for three blocks of the concrete dam. The plan pursued was similar to that followed in a number of other TVA dams. A series of observation points was established on a line transverse to the dam axis and located at about the center of the block being tested. At each point, a hole was drilled about 3 feet into the foundation rock. This hole was covered with a wooden box filled with gravel. From the box, a pipe was laid following the foundation rock surface to a point beneath the drainage gallery of the dam. From this point, a vertical pipe leads to the gallery. In the gallery the end of the pipe was covered with a cap tapped for a simple valve cock. If the intensity of pressure in the vicinity of the observation point was sufficient to produce a flow into the gallery, this pressure could be determined by the use of a pressure gage screwed into the valve cock. If the pressure was insufficient for this kind of measurement, it could still be determined by sounding in the vertical pipe, which in this case acted as a piezometer. Figure 157 presents the condensation of a number of sets of observations. The line at the top of each diagram represents an average elevation of the foundation contact. Since the observations were made at different times and at different reservoir levels, they have been reduced to a common percentage basis, using the total height between headwater and foundation as 100 percent. The designated control point is the floor of the drainage gallery, where no greater uplift pressure can exist than that determined by the outlets into the gallery at this point.

The lines designated as "calculated median" are the mean of about half a dozen selected measurements in the period from 1943 to 1948. In comparison, the most recent measurement, made April 30, 1948, is shown by itself as representing the most recent single observation. The diagrams also show the intensity of uplift pressure assumed for the design of the dam.

For block No. 11 the median line and the most recent line are almost coincident, showing a condition of great stability. In block No. 14 there has been at various times in the past a considerable pressure at point No. 5, which in one instance practically reached the assumed design line. This excess pressure has, however, apparently disappeared. The following explanation is given: The dam is underlaid by a massive formation of dolomite in which numerous joints and other openings occurred. As explained in the construction chapter, these were a source of many difficulties in the construction of the dam. However, the excavation, foundation treatment, and cut-off grouting were all carried to such a point that the foundation was considered reasonably tight. The soundness of this conclusion is evidenced by figure 156, showing the total drainage. It appeared, so far as block No. 14 was concerned, that some minor channel existed which was not stopped by the grout curtain and that this channel communicated with observation point No. 5. This channel now appears to be stopped by sediment or deposits so that the reading of April 30, 1948, appears to have the normal pattern and to be free from the effect of any such open passage.

A similar performance, but to a less degree, was noted in block No. 21. The general conclusion may be made from these observations that intensity of foundation uplift in the period of 5 years since construction has gradually diminished and has always been well below the design assumption.

Drainage measurements

Figure 156 presents a record of the total flow into the drainage gallery, which extends the full length of the concrete dam and is quite variable in elevation.

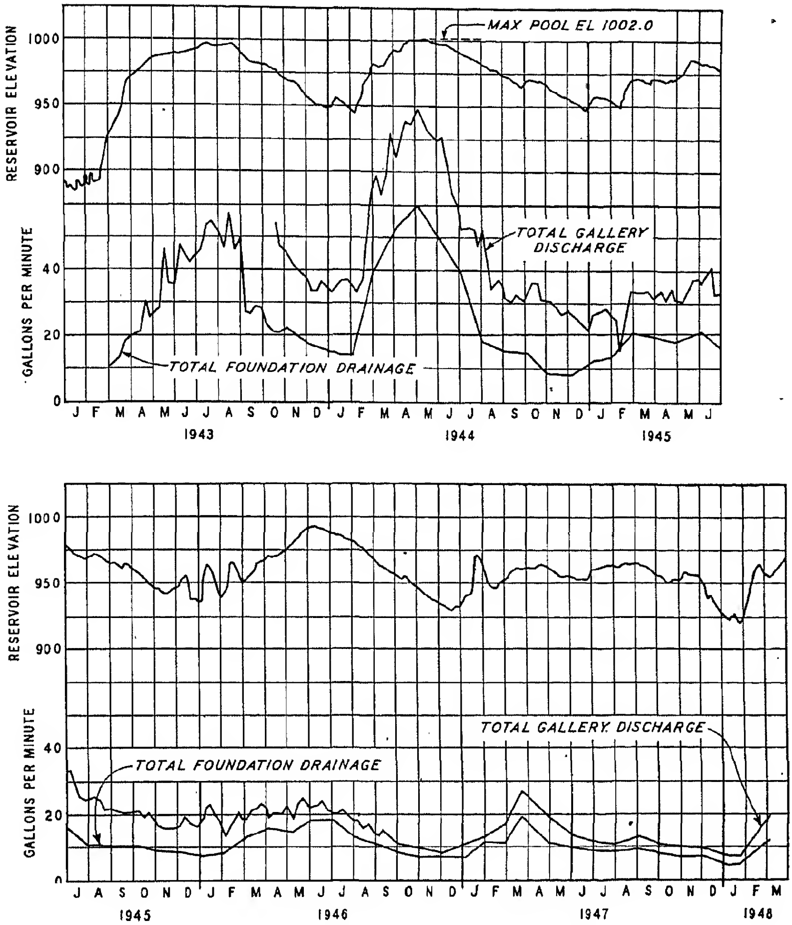

FIGURE 156.—*Foundation drain-hole discharges.*

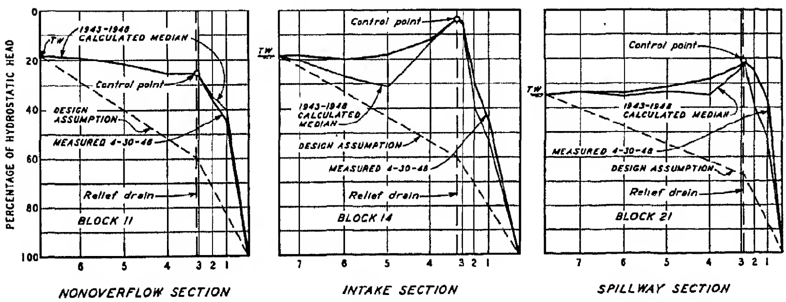

FIGURE 157.—*Uplift investigation.*

This drainage is collected and conducted to the powerhouse sump under normal conditions. Just before entering the connection to the sump, the drainage is measured by V-notch weirs, and this flow is plotted on the figure as the "total gallery discharge." The line designated "total foundation drainage" represents the sum of individual measurements made on the foundation drainage wells. The area between the two lines represents water passing through the concrete structure and entering the drainage gallery. This water may enter through contraction joints where it would have to bypass metal seals; it may enter through the drainage wells provided in the structure itself above the gallery or it may enter through pores and cracks in the concrete itself. Visual observation has shown leakage to occur in all three of these categories.

The first part of the record, which covers somewhat over 3 years, shows a number of variations in the curves which are not in evidence in the later observations. This difference arises from the fact that the observations were first made at weekly intervals. Gradually this period was lengthened so that for the past 2 years they have only been made at monthly intervals. In fact, the detailed measurements of the foundation drain wells have been made on only a monthly basis since January 1944.

Two facts are evident from this record. Aside from the general observation that the foundation drainage has never exceeded the rather moderate figure of 60 gallons per minute, this quantity has been gradually reducing. It is definitely less now than in 1943 and 1944, even if the measured discharges be adjusted to the full reservoir condition.

The concrete seepage or leakage, which was nearly 30 gallons per minute in April 1944, has also materially reduced. It appears that some pores or openings may have been stopped by sediment, or that autogenous healing of cracks may be responsible for this reduction. Swelling of submerged concrete may be responsible for the reduction of flow through contraction joints.

It is highly significant that the reduction of flow shown in figure 156 has not been accompanied by any increase in the foundation uplift pressure, which in fact has actually tended to diminish during the same period. These observations are believed to reflect a highly satisfactory condition of the dam so far as these two features are concerned.

Appendix D

PERSONNEL

The chart shown in figure 158 represents the organization of the Tennessee Valley Authority during the construction period of the Douglas project. Following the outline of this chart a limited list of key personnel is given, including those whose responsibility placed them in policy-making positions, insofar as those positions affected the Douglas project along with other TVA projects during the same period. A more extensive list of supervisory personnel is given, particularly covering the Division of Water Control in the River Channel, which includes actual engineering and construction personnel of the Douglas job. Various changes in the organizational structure occurred during the construction period, and the arrangement shown is considered to be the most representative. It is regretted that space does not permit the listing of all persons who were identified with the project.

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Vice Chairman

David E. Lilienthal
Chairman

James P. Pope
Director

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General Manager

Gordon R. Clapp

Budget Office
Paul W. Ager

Information Office
W. L. Sturdevant

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George F. Gant, Director
Harry L. Case, Assistant to Director, after July 1942

CLASSIFICATION
(Personnel services staff, after December 1942)

Carl L. Richey, until February 1943

Clement J. Sobotka, after February 1943

PERSONNEL RELATIONS

E. B. Shultz

EMPLOYMENT

(Office of the chief personnel officer, after December 1942)

George Slover

TRAINING

Malcolm G. Little, until August 1943

Wm. J. McGlothlin, after August 1943

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Coy E. Fulton

FINANCE

E. Arnold Sunstrom, Comptroller
Jerry F. Stone, Assistant
Glenn P. Smith, Assistant

TREASURER

H. K. Robinson

PROCEDURES

W. H. Raudenbush

AUDITING

A. J. Robertson

CENTRAL ACCOUNTING

W. A. Jensen

CONSTRUCTION ACCOUNTING

Paul Fahey

PROPERTY RECORDS

W. J. Pollock

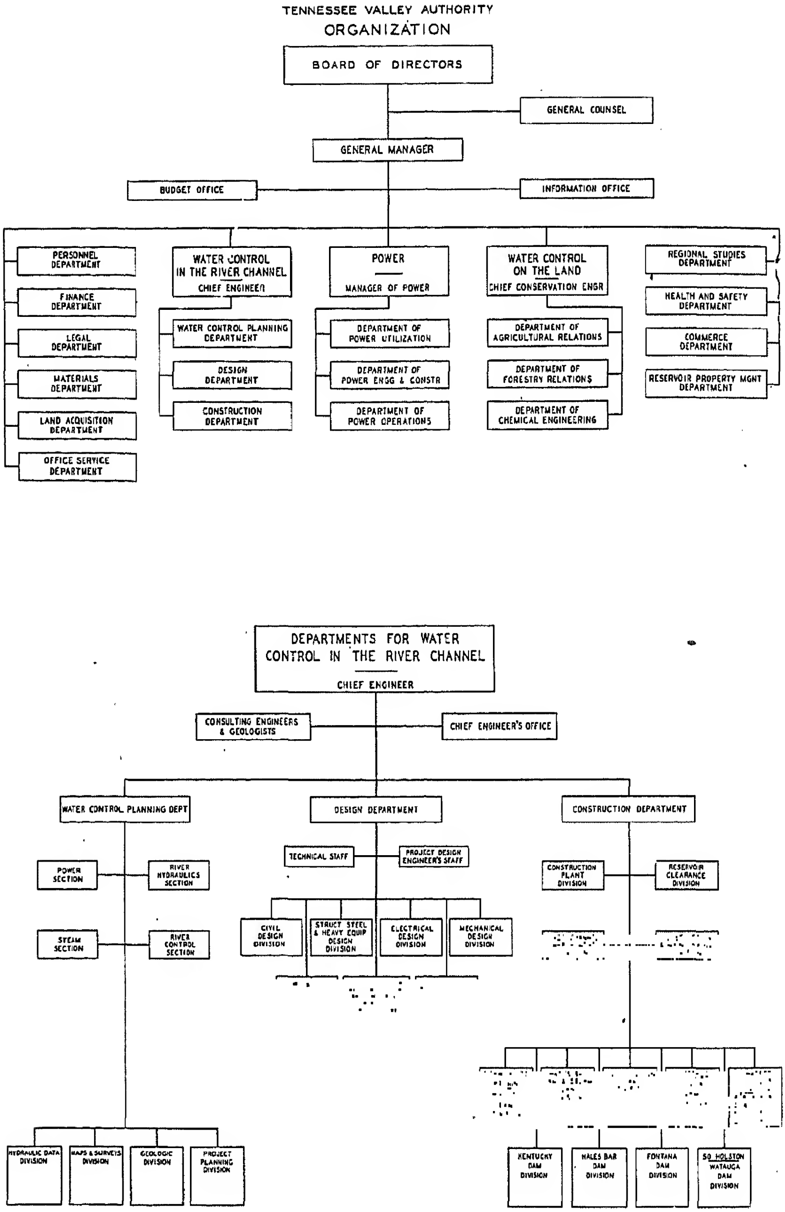

FIGURE 158.—*Organization chart.*

LEGAL

William C. Fitts, Jr., General Counsel

Joseph C. Swidler, until June 1943
Thomas J. Griffin
H. James Hitching
Charles J. McCarthy

MATERIALS

Charles H. Garity, Director
John L. Neely, Jr., Assistant, until July 1942
L. B. Rockwell, Assistant to the Director, after June 1943

CONTRACTS

O. F. Wasmansdorff, until July 1942
R. M. Mills, after July 1942

PROCUREMENT

W. J. Hagan, Jr.

SPECIFICATIONS

R. M. Mills, until July 1942
A. R. Holbrook, after July 1942

INSPECTION

P. B. Bruce

TRAFFIC (until July 1942)
TRAFFIC AND EXPEDITING (after July 1942)

L. B. Rockwell, until July 1942
John L. Neely, Jr., after July 1942

LAND ACQUISITION

John I. Snyder, Director
E. W. Cowling, Jr., Assistant, until March 1943
R. J. Partain, Assistant to the Director

SUPERVISOR OF TITLES

Leo L. Cole, Jr.

CHIEF TITLE EXAMINER

J. R. Perry

BOARD OF APPRAISAL AND REVIEW

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J. L. Burdette
W. E. Sanford
J. C. White

CHIEF LAND BUYER

L. M. Parrish

DOUGLAS DIVISION CHIEF

R. J. Coker

APPRAISAL COMMITTEE CHAIRMAN

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OFFICE SERVICE

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H. F. Gough, Assistant to the Director, after October 1942

OFFICE OPERATIONS DIVISION

R. M. Jones, Jr., until December 1942
P. W. Swenson, until July 1943
R. M. Jones, Jr., after July 1943

TRANSPORTATION

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SPACE AND COMMUNICATIONS STAFF (ended July 1943)

J. Gordon Reid, until June 1942
A. Richardson, until December 1942
R. M. Jones, Jr., until July 1943

OFFICE PROCEDURES AND STANDARDS STAFF (until July 1943)
OFFICE MANAGEMENT STAFF (after July 1943)

C. O. Libbey

WATER CONTROL IN THE RIVER CHANNEL

Theodore B. Parker, Chief Engineer, until June 1943
C. E. Blee, Chief Engineer, after June 1943
R. A. Monroe, Assistant, after June 1943
Harry Wiersema, Assistant to the Chief Engineer, after May 1942

GENERAL OFFICE ENGINEER (until May 1942)

Harry Wiersema

Burgess B. Brier
Albert B. Wilkinson
George E. Tomlinson
William A. Chalkley

CHIEF ENGINEER'S OFFICE
(after May 1942)

Burgess B. Brier
Albert B. Wilkinson

Van Court M. Hare, after July 1942
R. L. Forshay, after October 1943

William A. Chalkley, until June 1943

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W. H. McAlpine

J. L. Savage
C. P. Berkey
W. F. Prouty

O. N. Floyd
W. F. Uhl

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James S. Bowman, Chief Water Control Planning Engineer, after April 1943
James S. Bowman, Assistant, until April 1943

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E. J. Rutter

POWER STUDIES

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Reed A. Elliot
J. K. Turner

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B. C. Moneymaker

RIVER CONTROL

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D. Charlton
G. H. Hickox
J. Smallshaw
J. H. Wilkinson
B. E. Morriss, until September 1942
M. A. Churchill
Ritchey Hume
W. P. Clark
R. W. Gay

PROJECT PLANNING

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Arthur Schweier
C. W. Okey
L. H. Clouser
D. H. Mattern
B. R. Fuller
E. S. Weed
H. L. Southerland

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R. E. Frierson
P. F. Meredith, until May 1942
J. F. Barksdale
C. Shalibo
F. W. Truss
H. J. Kelly, until June 1942
Paul Morris
C. C. Miner
W. B. Jackson
C. M. Dubois

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W. B. Allen, Assistant

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J. E. Moreland, until August 1942
Erwin Harsch, after August 1942

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Richard E. Behnke, until March 1943
C. W. Bohner, after March 1943

HIGHWAY AND RAILROAD BRIDGES

K. C. Roberts, after August 1942

MECHANICAL ENGINEERING

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H. J. Petersen, after October 1942

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O. Hoebel

Administration

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E. F. Newman, after December 1942

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J. C. Nowell, Project Engineer, until February 1943
M. L. Dickinson, Project Engineer, after February 1943
F. E. Junior, Project Engineer, Highways and Railroads, after May 1942
J. P. Kennell, Electrical Engineering

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MECHANICAL ENGINEERING
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CIVIL ENGINEERING
A. A. Meyer

STRUCTURAL STEEL AND HEAVY EQUIPMENT
K. C. Roberts

ELECTRICAL ENGINEERING
Sven Kraven

HIGHWAY AND RAILROAD FIELD ENGINEERING
E. M. Arnold

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Thomas Benson, after May 1942

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Perry J. Freeman

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Douglas Dam Construction

Lee G. Warren, Project Manager, until June 1943
James S. Lewis, Acting Project Manager, after December 1943
T. F. Taylor, Construction Engineer, until October 1943
John W. Clarke, Assistant Construction Engineer, until July 1943

OFFICE ENGINEERING
Josef C. Patchen

ELECTRICAL ENGINEERING
Edward Woodbury

FIELD ENGINEERING
E. S. Crockett
R. K. Niece
W. R. Carpenter

BACKWATER PROTECTION
Fred G. Blackwell

MATERIALS TESTING AND CONCRETE INSPECTION
William D. Nowlin

FOUNDATION TREATMENT
P. L. Guthrie

CONSTRUCTION

James S. Lewis, Jr., Construction Superintendent, until December 1943
J. L. Jones, Assistant, until September 1942
R. C. Perkins, Assistant, after September 1942
Daniel Bowman, General Foreman, until May 1943
C. L. Drew, General Foreman, until May 1943
R. D. Holden, General Labor Foreman
H. D. Irvin, General Mechanical Foreman, until April 1943
T. R. Watts, General Steamfitter Foreman
R. P. King, General Structural Steel Foreman, until August 1943
E. A. Kelly, General Electrical Foreman, until January 1943
Carl S. Dress, General Electrical Foreman, after January 1943
G. F. Brandt, General Carpenter Foreman, until June 1943
L. E. Perew, General Painter Foreman

ACCOUNTING

O. A. Nystrom, Project Accountant, until July 1943
R. L. Grandy, Project Accountant, after July 1943
J. L. Kiser, Accounting
V. M. Leach, Costs, until September 1943
J. C. Bresnahan, Costs, after September 1943
E. A. Browne, Timekeeping
M. H. Segrest, Warehouse

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Robert T. Colburn, Construction Plant Engineer

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A. F. Hedman, Structural Engineer
T. S. Whitehouse, Electrical Engineer, until May 1943
John C. Buchanan, Electrical Engineer, after May 1943

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Reservoir Clearance

Howard E. Davis

ADMINISTRATIVE

William R. Holden
J. W. Williams

AREA SUPERINTENDENT

P. E. Brooks

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Merrill DeMerit, Chief Power Engineer
A. H. Sullivan, General Office Engineer
Llewellyn Evans, Chief Consulting Electrical Engineer

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W. W. Woodruff

UTILIZATION

Walton Seymour

WATER CONTROL ON THE LAND

Neil Bass, Chief Conservation Engineer

FORESTRY

Willis M. Baker

AGRICULTURE

J. C. McAmis

CHEMICAL ENGINEERING

A. M. Miller

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Tracy B. Augur, Assistant to the Director

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Roland A. Wank

GOVERNMENT RESEARCH

Lawrence L. Durisch

URBAN COMMUNITY RELATIONS

Raymond F. Leonard

RECREATION AND PUBLIC GROUNDS

Carroll A. Towne

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O. M. Derryberry, Assistant to the Director

EASTERN DIVISION

M. F. Langston

Project Medical Officer

L. E. Fraser, until November 1943
S. H. Freas, after November 1943

SANITATION

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SERVICE UNITS

R. B. Watson

WESTERN DIVISION

S. F. Strain

SAFETY

H. H. Hayes

Project Construction Safety Officer

Lamar W. Griffith

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H. P. Emerson, Assistant to the Director
W. H. Vaughan, Technical Assistant to the Director

C. T. Barker
C. J. Hurd
A. D. Spottswood, until December 1943
R. B. Taylor

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J. Ed Campbell, Assistant

AREA PROPERTIES MANAGER
Herbert E. Hudson

FAMILY REMOVAL
Dorothy G. Barber
W. R. West

RETIREMENT SYSTEM OF THE TENNESSEE VALLEY AUTHORITY

(Reproduced in Technical Report No. 6, The Chickamauga Project.)

EMPLOYEE RELATIONSHIP POLICY

(Reproduced in Technical Report No. 6, The Chickamauga Project)

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TABLE 48.—*Labor classifications and hourly rates of pay*

Classification	Effective Jan. 1, 1937	Effective Jan. 1, 1938	Effective Jan. 1, 1939	Effective Jan. 1, 1940	Effective Jan. 1, 1941	Effective Jan. 1, 1942	Effective Jan. 1, 1943
Apprentices	$0.60–$0.75	$0.475–$0.90	$0.475–$0.90	$0.475–$0.90	$0.50–$0.95	$0.65	$0.65
Armature winder	1.10	1.25	1.25	1.25	1.375	1.50	1.50
Asbestos worker (heat insul.)	1.10	1.125	1.125	1.25	1.25	1.375	1.50
Automotive grader operator	.75	.75– .85	.85– 1.00	.85– 1.00	1.00	1.25	1.25
Ax filer			.625	.625	.625	.625	.625
Blacksmith	1.10	1.125	1.175	1.25	1.25	1.375	1.375
Boilermaker	1.10	1.125	1.25	1.25	1.25	1.50	1.50
Bolt threading machine operator		.75	.75	.775	.775	.775	.775
Bricklayers (brick and stonemason)	1.25	1.375	1.50	1.50	1.50	1.50	1.625
Building trades (unclassified)	1.10	1.125	1.125	1.125	1.125	1.125	
Bulldozer operator	.75	.75– .85	.85 –1.00	.85– 1.00	1.00	1.25	1.25
Cableway head tower engineman			1.00	1.00	1.00	1.00	
Cableway operator	1.50	1.50	1.50	1.50	1.50	1.50	
Cableway signalman	1.25	1.25	1.25	1.25	1.32	1.50	
Carpenter (form and finish)	1.10	1.125	1.125	1.125	1.25	1.25	1.25
Carry-all operator (Le Tourneau)	1.00	1.00	1.125	1.25	1.25	1.25	1.25
Cement pump operator				.85	.85	.85	.85
Cement pump operator helper			.625	.625	.625	.625	.625
Cement mixing plant foreman			1.25	1.50	1.50	1.50	1.50
Compressor operator (portable)	.60– .75	.75	1.00	1.00	1.00	1.00	1.00
Heavy duty compressor operator	1.00	1.125	1.175	1.25	1.25	1.25	1.25
Concrete finisher	1.10	1.25	1.25	1.25	1.25		
Concrete mixer operator	.60– .75	.75– 1.00	.75 –1.00	1.00– 1.25	1.00– 1.25	1.00–1.25	1.00–1.25
Concrete placing foreman			1.25	1.25	1.25	1.25	1.25
Concrete puddler	.55	.575	.575	.575	.60	.60	.60
Conveyor operator		.625	.75	.75	.75	.75	.75
Core drill foreman		1.25	1.25	1.25	1.25	1.25	1.25
Core drill helper		.75	.75	.75	.75	.75	.75
Core drill operator	1.00	1.00	1.00	1.00	1.125	1.125	1.125
Crane car operator			.85	.85	.85	1.00	1.00
Crane or derrick operator	1.25– 1.50	1.50	1.50	1.50	1.50	1.50	1.625
Crushing plant foreman		1.375	1.375	1.375	1.375	1.375	1.375
Crushing plant operator		1.00	1.00	1.00	1.00	1.00	1.00
Crushing plant helper		.75	.75	.75	.75	.75	.75
Deck hand		.625	.625	.625	.625	.625	.625
Diamond drill setter		1.125	1.175	1.175			
Dinkey operator	.75	.75	.85	.85			
Dragline operator		1.25–1.50	1.50	1.50	1.50	1.50	1.625
Dredge booster pump operator			1.00	1.00	1.00	1.00	1.00
Drill bit grinder		.75	.75	.775	.775	.775	.775
Drill-dresser machine operator (drill-sharpener operator)	1.10	1.125	1.175	1.25	1.25	1.375	1.375
Electrician	1.10	1.25	1.25	1.25	1.375	1.50	1.50

Elevating grader operator	1.00	1.00	1.125	1.125	1.25	1.375	1.375
Excavating foreman				1.25	1.25	1.25	1.25
Fireman	.75	.75	.75	.75	.75	.90	1.00
Flagman	.60	.625	.75	.75	.75	.85	.85
Foreman:							
Labor	1.10	1.125	1.125	1.125	1.125		1.25
Skilled trades	1.25 [1] 1.50	1.375 [1] 1.625	1.375 [1] 1.75	1.375 [1] 1.75	1.375 [1] 1.75	1.375 [1] 1.75	1.375 [1] 1.875
Form stripper		.75	.75	.75	.75	.85	.85
Gas mechanic		1.125	1.25	1.25	1.25	1.375	1.50
Glaziers	1.10	1.125	1.125	1.125	1.125	1.25	1.25
Grade foreman			1.25	1.25	1.25	1.25	1.25
Grader operator	.75	.75	1.00	1.00	1.00	1.25	1.25
Groundman:							
Line crew		.625	.75	.75	.775	.775	.85
Trainee				.65	.65	.65	.65
Helpers	.60-.75	.75	.75	.775	.775		
Hoist operators:							
2 drums	1.10	1.25	1.25	1.25	1.25	1.25	1.375
1 drum	1.00	1.00	1.00	1.00	1.00	1.00	1.25
Hydraulic monitor operator, (nozzleman, sluicing)				.75	.75	.75	.75
Ironworker, ornamental	1.25	1.25	1.375	1.375	1.50	1.50	1.50
Jackhammer operator	.60	.625	.625	.625	.70	.75	.75
Labor, unclassified	.45	.475	.475	.475	.50	.50	.525
Larvieldal boat operator			.625	.625	.625	.625	.625
Lathers	1.10	1.125	1.125	1.125	1.25	1.50	1.50
LeTourneau operator	1.00	1.00	1.125	1.25	1.32		
Lineman	1.10	1.25	1.25	1.25	1.375	1.50	1.50
Loading machine operator				.75	.75	.75	.75
Locomotive operator	1.10	1.125	1.125-1.25	1.125-1.25	1.125	1.00-1.25	1.25-1.375
Machinist and general mechanic	1.10	1.125	1.25	1.25	1.25	1.375	1.375
Marble setter		1.25	1.50	1.50	1.50	1.50	1.50
Marine engineer:							
50 tons or over	1.10	1.125	1.25	1.25	1.25	1.25	1.25
Less than 50 tons	1.00	1.00	1.125	1.125	1.125	1.125	1.125
Marine pilot:							
50 tons or over	1.10	1.125	1.25	1.25	1.25	1.25	1.25
Less than 50 tons	1.00	1.00	1.125	1.125	1.125	1.125	1.125
Masons, brick and stone	1.25	1.375	1.50	1.50		1.50	1.625
Mason tender	.60						.65
Millwright	1.10	1.125	1.25	1.25	1.25	1.25	1.25
Mortar mixer	.75	.75	.75	.75	.75	.75	.75
Motorboat and tugboat operator	.60-.75	.625-.75	.625-.75	.625-.75	.625-.75	.625-.75	.625-.75
Oiler	.60-.75	.75	.75	.75	.75	.90	.90
Ornamental ironworker	1.25	1.25	1.375	1.375	1.50	1.50	1.50
Painters and decorators	1.10	1.125	1.125	1.125	1.125	1.25	1.25
Painters, sign	1.10	1.125	1.125	1.125	1.125	1.25	1.25
Pan scraper operator					1.50	1.50	1.50

[1] Based on rates of trade supervised, with $0.25 differential.

TABLE 48.—*Labor classifications and hourly rates of pay*—Continued

Classification	Effective Jan. 1, 1937	Effective Jan. 1, 1938	Effective Jan. 1, 1939	Effective Jan. 1, 1940	Effective Jan. 1, 1941	Effective Jan. 1, 1942	Effective Jan. 1, 1943
Paving kettle man		$0.625	$0.625	$0.625	$0.625	$0.625	$0.625
Pile driver	$1.10				1.50	1.50	1.625
Pipefitter	1.25						
Plasterers	1.25	1.25-1.375	1.375-1.50	1.375-1.50		1.50	1.5625
Plumber and steamfitter	1.25	1.25	1.375	1.375	1.50	1.50	1.625
Portable crusher feeder			.575	.575	.575	.60	.60
Portable crusher foreman			1.125	1.125	1.125	1.125	1.125
Portable crusher operator			.75	.75	.75	.75	.75
Powderman	.75	1.00	1.00	1.00	1.00	1.00	1.00
Powder foreman		1.25	1.25	1.25	1.25	1.25	1.25
Powderman helper		.625	.625	.625	.625	.625	.625
Primary crusher operator			1.125	1.125	1.125	1.125	1.125
Pump operator	.60-.75	.60-.75	.75	.75	.75	1.00	1.00
Rigger	1.25						
Road machine operator	.75						
Road roller operator	.75	.75	1.00	1.00	1.00-1.25	1.00-1.25	1.00-1.25
Roofer	1.10	1.125	1.125	1.125		1.125	1.125
Sand classifier operator			.85	.85	.85	.85	.85
Saw filer	1.10	1.125	1.125	1.125	1.25	1.25	1.25
Sewer layer	.60	.625	.625	.625	.625	.625	.65
Shaft and tunnel foreman			1.25	1.25	1.25	1.25	1.25
Shaft and tunnel laborer			.575	.575	.575	.60	.60
Shaft and tunnel miner	.75	.75	.75	.75	.75	.75	1.00
Sheet metal worker	1.10	1.125	1.125	1.25	1.25	1.375	1.425
Shovel and dragline operator	1.25-1.50	1.25-1.50	1.50	1.50	1.50	1.50	1.625
Signal man (cableway)	1.25	1.25	1.25	1.25		1.50	
Steel worker, reinforcing (bending, placing, typing)	1.00	1.125	1.25	1.25		1.375	1.375
Steelworker, structural (erecting, riveting, heating)	1.25	1.25	1.375	1.375	1.50	1.50	1.50
Subforeman:							
Labor	.75	.75	.75	.75	.85		.85
Skilled trades	1.10-[2] 1.35	1.225-[2] 1.475	1.225-[2] 1.60	1.225-[2] 1.60	1.225-[2] 1.60	1.225-[2] 1.60	1.225-1.725
Teamster	.45-.60	.475-.625	.475-.625	.475-.625	.50-.625	.50-.625	.525-.65
Terrazzo worker		1.25	1.50	1.50	1.50	1.50	1.50
Tile setter		1.25	1.50	1.50	1.50	1.50	1.50
Tool dresser	1.10	1.125	1.175	1.25	1.25	1.375	1.375
Tractor and grader operator	.75	.75-.85	.85-1.00	.85-1.00	1.00	1.00-1.25	1.00-1.25
Transportation foreman			1.25	1.25	1.25	1.25	1.25
Trenching machine helper			.625	.625	.625	.625	.625
Trenching machine operator	1.10	1.125	1.125	1.25	1.25	1.25	1.375
Truck operator	.60-.75	.625-.85	.625-1.00	.625-1.00	.625-1.00	.65-1.00	.65-1.25
Wagondrill operator	.75	.75	.75	.75	.85	.90	.90
Watchman	.45	.475	.475	.475	.50	.50	.525

Welder	1.25	1.25	1.375	1.375	1.50		1.625
Well drill foreman			1.25	1.25	1.25	1.25	1.25
Well drill helper			.75	.75	.75	.75	.75
Well drill operator			1.00	1.00	1.125	1.125	1.125
Yard conductor		1.125	1.125	1.125	1.125	1.125	1.125
Yard foreman, switchman	[3] .75	1.00	1.00	1.00	1.00	1.00	1.00
RESERVOIR CLEARANCE [4]							
Clerical, first aid, laborer			$1.25	$1.25	$1.25		$0.625
Foreman, labor	$1.00					$1.25	1.25
Laborer						.50	.525
Machine operator	.85						
Motorboat and tugboat operator						.625-.75	.625-.75
Sawfiler	.75	$0.75	.75	.75	1.00	1.00	1.00
Tallyman							
Timber rigger	.625	.625	.75	.75	.75	.75	.75
Tree climber			.75	.75	.75		.75
Truck driver						.65-1.00	.65-1.00

[2] Based on rates of trades supervised, with $0.10 differential.
[3] Rate established during 1937.
[4] With these exceptions, rates for reservoir clearance work were the same as those paid on dam construction shown above.

Appendix E

MAJOR PURCHASES

Table 49.—*Major purchases of material and equipment*

Item	Vendor	Date of award	Contract price	F. o. b.
ARCHITECTURAL				
Millwork	Rhyne Lumber Co	Feb. 2, 1942	$2,273.49	Douglas dam site.
Lumber	Cleo Burchfield	do	1,873.40	Do.
Millwork	Southern Manufacturing Co.	Feb. 10, 1942	1,369.32	Do.
Steel sash	Truscon Steel Co	Mar. 31, 1942	3,976.00	Ewing.
Doors, frames, hardware, and accessories.	Superior Steel & Trim Co	Apr. 7, 1942	18,896.00	Do.
Steel railings, coping, and wall base plates.	Kerrigan Iron Works	Apr. 13, 1942	3,198.00	Do.
Steel louvers and vent grilles	do	Apr. 14, 1942	1,190.00	Do.
Steel stairs and railings	do	May 20, 1942	2,128.00	Do.
Service cabinets	Reliance Art Metal Co	Jun 19, 1942	571.50	Do.
Paint and paint materials	Gilman Paint & Varnish Co.	July 3, 1942	1,973.80	Do.
Do	Inemec Co	do	837.75	Douglas.
Nonload bearing tile	Chandler & Co	July 21, 1942	4,012.11	Ewing.
Concrete building bricks	Southern Cast Stone Co	do	2,275.00	Do.
Furring and lathing material.	Chandler & Co	July 27, 1942	1,585.00	Do.
Movable steel partitions	E. F. Houserman	July 28, 1942	1,591.00	Do.
Glazed wall tile and marble	I. A. Wild	Sept. 3, 1942	10,802.00	Do.
Acoustical tile	Len Herndon Co	Sept. 23, 1942	590.00	Douglas.
Roofing and flashing	Tennessee Roofing Co	Oct. 6, 1942	5,213.80	Do.
Paint and paint materials	Gilman Paint & Varnish Co.	Oct. 10, 1942	1,596.50	Sevierville.
Kitchen equipment	General Electric Supply Corp.	Oct. 15, 1942	1,376.08	Ewing.
Glass and glazing	Binswanger & Co	Dec. 2, 1942	1,207.00	Do.
Quarry tile floors and bases	The Art Mosaic & Tile Co	Dec. 7, 1942	2,087.00	Do.
Terrazzo floor, furnish and install.	do	Dec. 10, 1942	2,540.00	Installed.
Linoleum	Clemons Bros. Co	Jan. 8, 1943	1,475.00	Do.
Vacuum cleaner	The Spencer Turbine Co	Jan. 11, 1943	754.33	Ewing.
Tempered glass kick plates	Toledo Plate & Window Glass Co.	Apr. 7, 1943	3,173.73	Do.
ELECTRICAL				
Miscellaneous electrical supplies.	Graybar Electric Co	Feb. 3, 1942	3,977.47	Douglas dam site and Jefferson City.
Do	do	Feb. 4, 1942	2,845.65	Douglas Dam.
Do	do	do	754.53	Do.
Electrical supplies	do	Feb. 5, 1942	798.84	Do.
Transite conduit	Johns-Manville Sales Corp	Feb. 7, 1942	2,233.48	Sevierville.
Main transformers and reactors.	General Electric Co	Feb. 9, 1942	251,625.00	Do.
Generators	do	do	1,242,999.00	Erected.
Fiber conduit and fittings	Line Material Co	Feb. 11, 1942	5,417.90	Sevierville.
Poles	Brown Wood Preserving Co.	do	985.12	Jefferson City.
Oil circuit breaker	General Electric Co	Feb. 12, 1942	2,913.00	Sevierville.
Rigid steel conduit and fittings.	Graybar Electric Co	do	16,154.00	Do.
Indoor and outdoor disconnect combination.	General Electric Co	do	3,050.00	Do.
Indoor disconnect switches	Schweitzer & Conrad	Feb. 13, 1942	931.20	Do.
Main auxiliary power switchboard.	I. T. E. Circuit Breaker Co.	Feb. 18, 1942	19,771.00	Do.
161-kilovolt disconnect switches.	Electric Power Equipment Corp.	do	38,945.00	Do.
Recorders	Leeds & Northrup Co	do	11,362.00	Do.
Lighting fixtures and telephone boxes.	General Electric Supply Corp.	do	2,626.05	Do.
15-kilovolt indoor switch gear.	Allis-Chalmers Manufacturing Co.	Feb. 19, 1942	30,589.00	Do.
Auxiliary power switchboard.	General Electric Supply Corp.	do	13,513.66	Do.
Cable control and power circuits.	American Steel & Wire Co	Feb. 24, 1942	69,349.72	Do.

TABLE 49.—*Major purchases of material and equipment*—Continued

Item	Vendor	Date of award	Contract price	F. o. b.
ELECTRICAL—Con.				
Rubber insulated cable	Simplex Wire & Cable Co	Feb. 26, 1942	$8,477.52	Sevierville.
Station service transformers	Moloney Electric Co	do	3,171.00	Do.
Do	Allis-Chalmers Manufacturing Co.	Feb. 27, 1942	9,843.85	Do.
Telephone and signal equipment.	American Automatic Electric Sales.	do	8,912.00	Do.
Operation recording and annunciator equipment.	Autocall Co	do	10,322.50	Do.
Lightning arresters	General Electric Co	do	7,782.00	Do.
Pothead terminals	G & W Electric Specialty Co.	Mar. 2, 1942	2,093.65	Do.
Steel tube conductors	Murray W. Sales & Co	do	1,473.00	Do.
Lighting, heating, and control transformers.	Westinghouse Electric	do	522.46	Do.
Main control and annunciator battery.	The Electric Storage Battery Co.	do	4,618.85	Do.
161-kilovolt oil circuit breakers.	General Electric Co	Mar. 3, 1942	166,474.00	Do.
Motor control equipment	Allen & Bradley Co	do	879.92	Do.
Do	General Electric Supply Corp.	Mar. 5, 1942	516.75	Do.
Junction boxes and conduit fittings.	Graybar Electric Co	do	3,008.67	Do.
Carbon dioxide equipment	Walter Kidde & Co	Mar. 6, 1942	8,361.00	Do.
Lighting, heating, and control transformers.	General Electric Co	Mar. 9, 1942	2,449.57	Do.
Cable	Phelps-Dodge Copper Corp.	Mar. 10, 1942	25,133.29	Do.
Battery charging motor generator sets.	The Electric Products Co	Mar. 13, 1942	3,568.70	Do.
Bus clamps and ground connectors.	Penn-Union Electric Corp	do	3,570.30	Do.
Air conditioning switchboard.	General Electric Supply Corp.	do	3,864.00	Do.
Transformer embankment lighting.	Westinghouse Electric	Mar. 24, 1942	1,943.94	Do.
Water level gages	Leopold, Volpel & Co	do	1,995.30	Do.
Copper bars and tubes	Chase Brass & Copper Co	Mar. 27, 1942	3,072.02	Do.
Do	Phelps-Dodge Copper Corp	do	1,030.66	Do.
Main control switchboards	General Electric Co	do	33,359.00	Do.
Carrier current equipment	Westinghouse Electric	Mar. 31, 1942	20,586.00	Do.
Pedestal insulators	Southeast Joslyn Co	Apr. 9, 1942	5,737.50	Ewing.
Carrier current equipment.	General Electric Co	Apr. 10, 1942	14,926.00	Sevierville.
Motor control equipment	Graybar Electric Co	May 11, 1942	663.65	Do.
Ceiling outlet fixtures	Anemostat Corp. of America	Apr. 21, 1942	933.11	Do.
Lighting, heating, and power panelboards.	Graybar Electric Co	do	666.70	Do.
Do	do	do	1,115.90	Do.
Do	James Supply Co	do	3,365.00	Do.
Insulators and fittings	Ohio Brass Co	May 5, 1942	754.82	Ewing.
Insulators and fittings	Lapp Insulator Co	do	1,207.93	Sevierville.
Lens lighting fixtures and telephone boxes.	Summerour & Devine	June 24, 1942	2,686.54	Ewing.
Motors	Johnson Motors	June 25, 1942	1,824.00	Morristown.
Lighting fixtures and wiring devices.	Graybar Electric Co	July 3, 1942	1,157.68	Ewing.
Telephone cables and terminals.	do	July 22, 1942	556.35	Do.
Lighting fixtures and wiring devices.	General Electric Supply Corp.	do	1,462.82	Do.
Do	Roden Electric Supply Co	do	869.76	Do.
Rigid steel conduit	do	do	1,209.82	White Pine.
Lighting fixtures series transformers.	General Electric Co	July 27, 1942	730.80	Ewing.
Transmission towers	Lehigh Structural Steel Co	July 30, 1942	5,440.00	Jefferson City.
Floodlight projectors	Stokes Electric Co	Aug. 6, 1942	859.29	Ewing.
Do	Graybar Electric Co	do	1,041.60	Do.
Bare and weatherproof copper cable.	Nehring Electrical Works	Aug. 16, 1942	8,257.43	Sevierville.
Miscellaneous electrical materials.		Aug. 27, 1942	703.45	White Pine.
Fire extinguishing equipment.	Walter Kidde & Co	Aug. 28, 1942	1,210.53	Ewing.
Special lighting fixtures	Kurt Versen Co	Sept. 4, 1942	735.15	Sevierville.
Main transformers and reactors.	General Electric Co	Sept. 9, 1942	5,680.00	Ewing.
Electric insulating oil	Tide Water Associated Oil Co.	Nov. 2, 1942	1,399.95	Do.
Lighting panelboards	Graybar Electric Co	Nov. 6, 1942	713.00	Sevierville.
Lamps	General Electric Co	Jan. 8, 1943	904.75	Douglas Dam.
Fire extinguishing equipment.	Walter Kidde & Co	July 11, 1943	578.56	Do.

TABLE 49.—*Major purchases of material and equipment*—Continued

Item	Vendor	Date of award	Contract price	F. o. b.
STRUCTURAL				
Cement	Volunteer Portland Cement Co.	Feb. —, 1942	$1,025,000.00	Douglas Dam.
Do	Penn-Dixie Cement Corp	do	715,377.00	Do.
Wire rope	American Steel & Wire Co	Jan. 31, 1942	5,376.00	Sevierville.
Fire hydrants	American Radiator & Standard Sanitary Corp.	Feb. 2, 1942	982.80	Do.
Aggregate	Birmingham Slag Co	do	1,117,098.10	Douglas Dam.
Steel pipe	House-Hasson Hardware Co	do	12,990.60	Sevierville.
Lumber	W. P. Brown & Sons Lumber Co.	Feb. 3, 1942	15,325.00	Do.
Do	Burke & Hodges Lumber Co	do	3,110.00	Douglas Dam.
Do	Cleo Burchfield	do	1,250.00	Do.
Steel pipe	House-Hasson Hardware Co.	do	1,387.95	Sevierville.
Steel cylinders	Truitt Manufacturing Co	do	927.00	Do.
Lumber	Sevierville Lumber & Manufacturing Co.	Feb. 4, 1942	596.21	Douglas Dam.
Do	Rhyne Lumber Co	do	4,888.50	Do.
Do	Burke and Hodges Lumber Co.	do	7,039.39	Do.
Do	Cleo Burchfield	Feb. 5, 1942	7,525.00	Do.
Do	W. P. Brown & Sons Lumber Co.	do	8,925.00	Sevierville.
Do	W. A. Belcher Lumber Co	do	24,356.25	Do.
Do	Cleo Burchfield	do	941.36	Douglas Dam.
Do	W. P. Brown & Sons Lumber Co.	do	19,587.84	Sevierville.
Do	Sevierville Lumber & Manufacturing Co.	do	3,447.76	Douglas Dam.
Steel	Mount Vernon Bridge Co	Feb. 6, 1942	47,670.00	Sevierville.
Penstock liners	Chicago Bridge & Iron Co	do	72,510.00	Ewing.
Nails	Keystone Wire & Steel Co	Feb. 7, 1942	2,172.01	Jefferson City.
Lumber	Rhyne Lumber Co	do	9,913.31	Douglas Dam.
Steel sheets	Wheeling Steel Corp	Feb. 9, 1942	3,931.06	Jefferson City.
Copper water seals	C. G. Hussey & Co	do	4,064.64	Sevierville.
Nails	Continental Steel Corp	Feb. 10, 1942	1,588.05	White Pine.
Aggregate	Knoxville Sangravl Material Co.	do	1,040.00	Sevierville.
Tunnel gate frames	Wisconsin Bridge & Iron Co.	Feb. 11, 1942	2,289.00	Do.
Wire rope	A. Leschen & Sons Rope Co	do	2,121.00	Morristown.
Crushed stone	American Limestone Co	Feb. 12, 1942	900.00	White Pine.
Wire spikes	Atlantic Steel Co	do	502.34	Jefferson City.
Gate anchorages	Whitehead & Kales Co	do	38,795.00	Sevierville.
Tractor and winch	Brooks Equipment Co	Feb. 13, 1942	5,296.00	Douglas Dam.
Power shovel	Webster Manufacturing Co	do	1,209.50	Sevierville.
Draft tube gate guides	Lakeside Bridge & Steel	Feb. 17, 1942	8,451.00	Do.
Trashracks and guides	Bethlehem Steel Co	do	17,500.00	Do.
Lumber	W. E. Comstock	do	8,510.41	Jefferson City.
Do	Burke & Hodges Lumber Co.	do	2,465.05	Douglas Dam.
Barbed wire and fence staples.	Wheeler Steel Corp	Feb. 18, 1942	1,716.04	White Pine.
Trailers	Schultz Trailers, Inc	do	624.00	Jefferson City.
Aggregate	Knoxville Sangravl Material Co.	Feb. 19, 1942	3,325.00	White Pine.
Cross and switch ties	Southern Wood Preserving Co.	do	28,872.00	Ewing.
Gate guides and sill beams	Treadwell Construction Co	Feb. 20, 1942	6,220.00	Sevierville.
Lumber	W. P. Brown & Sons Lumber Co.	do	5,865.00	White Pine.
Do	Steel City Lumber Co	do	2,820.00	Do.
Do	W. A. Belcher Lumber Co	do	3,110.00	Do.
Do	Atlantic States Lumber Co	do	981.54	Jefferson City.
Crushed stone	Oliver King Sand & Lime Co.	Feb. 23, 1942	5,280.00	Sevierville.
Form lining	Dant & Russell, Inc	do	3,456.00	Do.
Furnace slag	Tennessee Products Corp	Feb. 24, 1942	7,700.00	Rockwood.
Sprinkler system	Crawford & Slyton	do	3,740.00	Douglas Dam.
Intake gate guides	Bethlehem Steel Co	Feb. 25, 1942	26,280.00	Sevierville.
Trashracks and guides	Arthur J. O'Leary & Son	do	22,525.00	Do.
Tyloops	Wilson - Weesner - Wilkinson Co.	do	7,800.00	Brooklyn, N. Y.
Anchor bolt assemblies	A. J. O'Leary & Son	do	2,550.37	Sevierville.
Aggregate	American Limestone Co	Feb. 26, 1942	873.60	Do.
Wire rope	A. Leschen & Sons Rope Co	do	3,330.00	Jefferson City.
Do	American Steel & Wire Co	do	2,980.00	Do.
Bolts, washers, spikes, etc	Birmingham Rail & Locomotive Co.	Feb. 27, 1942	1,457.40	Ewing.
Turn-outs	Weir Kilby Corp	do	2,250.00	Do.

TABLE 49.—*Major purchases of material and equipment*—Continued

Item	Vendor	Date of award	Contract price	F. o. b.
STRUCTURAL—Con.				
Nails and spikes	Republic Steel Corp	Mar. 1, 1942	$2, 165. 98	Jefferson City.
Structural steel and operating bridge.	American Bridge Co	Mar. 2, 1942	72, 395. 00	Ewing.
Sluice liners	Chicago Bridge & Iron Co	Mar. 3, 1942	53, 000. 00	Sevierville.
Track trucks	Brooks Equipment & Manufacturing Co.	do	33, 270. 00	Jefferson City.
Steel wire	Laclede Steel Co	Mar. 5, 1942	3, 738. 00	Morristown.
Crushed stone	American Limestone Co	Mar. 13, 1942	10, 250. 00	Sevierville.
River sand	O. B. Hodge	Mar. 16, 1942	6, 750. 00	Douglas Dam.
Pit run furnace slag	Tennessee Products Corp	do	9, 240. 00	Rockwood.
Burlap bags	Werthan Bag Corp	do	20, 480. 00	Jefferson City.
Crushed stone	T. K. Griffith	Mar. 18, 1942	32, 250. 00	Douglas Dam.
Utility trailers	Schultz Trailers, Inc	Mar. 20, 1942	23, 334. 00	Near Dandridge.
Vibrators	Mall Tool Co	Mar. 21, 1942	3, 103. 20	Jefferson City.
Do	Electric Tamper & Equipment Co.	do	11, 250. 00	Ludington, Mich.
Do	Viber Co	do	2, 680. 00	Jefferson City.
Steel pipe	The Interstate Pipe & Supply Co.	do	8, 950. 00	Sevierville.
Do	Noland Co	Mar. 23, 1942	4, 373. 49	Jefferson City.
Cattle guards	Fairbanks, Morse & Co	Mar. 27, 1942	1, 665. 95	Sevierville.
Bin and batching equipment.	Finn Equipment Co	do	1, 291. 92	White Pine.
Core drills and accessory equipment.	Sullivan Machinery Co	do	13, 747. 50	Jefferson City.
Steel bearing piles	Carnegie-Illinois Steel Corp	do	4, 188. 85	Sevierville.
Crushed stone	American Limestone Co	Mar. 31, 1942	1, 930. 00	White Pine.
Drilling and testing	Sprague & Henwood, Inc	Apr. 1, 1942	18, 595. 00	Job site.
Steel bearing piles	Carnegie-Illinois Steel Corp.	Apr. 3, 1942	572. 56	White Pine.
Hacksaws	Dederick Machinery Co	do	1, 075. 00	Jefferson City.
Crushed stone	American Limestone Co	do	3, 157. 50	White Pine.
Generator hatch covers	Connery Construction Co	Apr. 4, 1942	17, 550. 00	Ewing.
Galvanized structural steel	Lehigh Structural Steel Co	Apr. 6, 1942	18, 490. 00	Do.
Cast-iron crib forms	Jones Foundry Co	do	1, 636. 30	Newport.
Structural steel and miscellaneous accessories.	Southern Steel Works Co	Apr. 7, 1942	5, 535. 00	Do.
Air hose	Knoxville Belting & Supply Co.	Apr. 9, 1942	2, 111. 00	Douglas Dam.
Grouting pumps	The Colonial Iron Works Co.	Apr. 11, 1942	1, 288. 00	Jefferson City.
Stone chips	American Limestone Co	Apr. 14, 1942	1, 720. 00	White Pine.
Tar	Gamble Construction Co	Apr. 15, 1942	3, 729. 00	Near Dandridge.
Lumber	Burke & Hodges Lumber Co.	do	4, 027. 23	Job site.
Aggregate	American Limestone Co	Apr. 16, 1942	2, 940. 70	White Pine.
Do	do	do	1, 700. 00	Newport.
Steel superstructure	American Bridge Co	Apr. 17, 1942	146, 507. 20	Job site, Leadville.
Air hose	Owen-Richards Co	do	1, 430. 60	Douglas Dam.
Do	Knoxville Belting & Supply Co.	do	2, 566. 60	Do.
Derrick	Finn Equipment Co	Apr. 20, 1942	6, 750. 00	Detroit, Mich.
Carbon steel bars	Atlantic Steel Co	Apr. 23, 1942	1, 028. 00	Ewing.
Sand	Birmingham Slag Co	do	22, 400. 00	Job site.
Sheet metal bus housing	The Kirk & Blum Manufacturing Co.	Apr. 24, 1942	6, 964. 00	Sevierville.
Bolts	Boss Bolt & Nut Co	do	1, 919. 87	Douglas Dam.
Hex nuts	Oliver Iron & Steel Corp	do	636. 70	Jefferson City.
Steel wire	Laclede Steel Co	Apr. 25, 1942	1, 822. 50	Ewing.
Chloride	American Cyanamid & Chemical Corp.	do	3, 220. 00	Morristown.
Used hoist	Finn Equipment Co	do	2, 100. 00	Detroit, Mich.
Do	Equipment Corp. of America	do	1, 789. 00	Jefferson City.
Lumber	Rhyne Lumber Co	Apr. 28, 1942	8, 000. 00	Douglas Dam.
Do	Chatsworth Lumber Co	do	2, 906. 25	Ewing
Do	W. A. Belcher Lumber Co	do	25, 500. 00	Do.
Do	W. P. Brown & Sons Lumber Co.	do	17, 795. 00	Do.
Pump	Berkeley Pump Corp	Apr. 29, 1942	864. 00	Knoxville.
Structural steel	Southern Steel Works Co	do	16, 983. 00	White Pine.
Hoist chains	S. G. Taylor Chain Co	May 6, 1942	1, 003. 00	Sevierville.
Suction hose	Slip-Not Belting Corp	do	722. 25	White Pine.
Bituminous material	Gamble Construction Co	do	6, 160. 00	Douglas Dam.
Asphalt	Burke & Hodges Lumber Co.	May 8, 1942	72, 000. 00	Ewing.
Grador belts	Knoxville Belting & Supply Co.	do	10, 058. 88	Douglas Dam.
Nails and spikes	Republic Steel Corp	May 12, 1942	1, 514. 50	White Pine.
Steel superstructure for bridge.	American Bridge Co	May 17, 1942	120, 000. 00	At site.

TABLE 49.—*Major purchases of material and equipment*—Continued

Item	Vendor	Date of award	Contract price	F. o. b.
STRUCTURAL—Con.				
Concrete treating compound.	Solvents & Plastics Co.	May 18, 1942	$10, 400. 00	Ewing.
Rail	Tennessee Coal, Iron & Railroad Co.	May 20, 1942	62, 078. 25	Rankin.
Generator stair and walkway.	Roanoke Iron & Bridge Works.	May 22, 1942	2, 055. 00	Ewing.
Rail joints	The Rail Joint Co.	May 23, 1942	5, 288. 20	Rankin.
Bolts, spikes, and tie plates	Tennessee Coal, Iron & Railroad Co.	do	16, 543. 33	Do.
Rail anchors	American Fork & Hoe Co.	do	3, 089. 90	Do.
Wire nails	Wheeling Steel Corp.	do	4, 108. 80	Ewing.
Fire alarm system	American District Telegraph Co.	May 26, 1942	17, 897. 00	Douglas Dam.
Coal	Southern Coal & Coke Co.	May 27, 1942	3, 434. 00	Ewing.
Asbestos-cement cable tray	Johns-Manville Sales Corp.	do	1, 838. 30	Do.
Tile and pipe	Sherman Concrete Pipe Co.	May 28, 1942	2, 701. 80	Douglas Dam.
Rails and accessories	Carnegie-Illinois Steel Corp.	do	3, 193. 00	Ewing.
Crushed stone	American Limestone Co.	May 29, 1942	16, 200. 00	White Pine.
Construction of highway	Codell Construction Co.	June 3, 1942	149, 315. 00	Job site.
Lumber	W. P. Brown & Sons Lumber Co.	do	3, 939. 00	White Pine.
Construction of highway	Richard E. Martin	June 4, 1942	285, 330. 00	Job site.
Structural steel	Southern Steel Works Co.	June 6, 1942	4, 865. 00	White Pine.
Concrete culvert pipe	Sherman Concrete Pipe Co.	do	10, 850. 00	Dandridge.
Pipe fittings	Hajoca Corp.	June 9, 1942	887. 13	Douglas Dam.
Creosoted poles	Southern Wood Preserving Co.	do	2, 184. 92	White Pine.
Black steel tubing	Laclede Steel Co.	June 10, 1942	5, 625. 00	Ewing.
Structural steel gate hoist rails.	Carnegie-Illinois Steel Corp.	do	946. 78	Sevierville.
Pipe and fittings	American Radiator & Standard Sanitary Corp.	do	3, 273. 26	Ewing.
Lumber	Burke & Hodges Lumber Co.	June 11, 1942	1, 943. 85	White Pine.
Aggregate	American Limestone Co.	June 12, 1942	1, 970. 00	Rankin.
Pipe and fittings	National Cast Iron Pipe Co.	do	1, 565. 38	Ewing.
Miscellaneous steel	Carolina Steel & Iron Co.	June 17, 1942	9, 119. 00	Do.
Concrete culvert pipe	Sherman Concrete Pipe Co.	June 18, 1942	30, 917. 20	Dandridge.
Tar	Gamble Construction Co.	June 19, 1942	1, 581. 50	Job site.
Crushed stone chips	American Limestone Co.	do	1, 764. 00	Strawberry Plains.
Stone chips	do	June 20, 1942	860. 00	White Pine.
Crushed stone	Walters & Prater	June 22, 1942	47, 000. 00	Nina.
Interlocking	General Railway Signal Co.	do	10, 200. 00	White Pine.
Lumber	W. P. Brown & Sons Lumber Co.	June 23, 1942	1, 702. 50	Do.
Do	Burke & Hodges Lumber Co.	do	2, 675. 00	Newport.
Steel floor grating	Reliance Steel Products Co.	June 30, 1942	1, 290. 00	Ewing.
Sand	Knoxville Sangravl Material Co.	July 1, 1942	6, 125. 00	White Pine.
Gravel	do	do	8, 750. 00	Do.
Hand-railing, spillway intake.	Birmingham Ornamental Co.	do	6, 615. 00	Ewing.
Construction of highway	Clark, Kearney & Stark	July 6, 1942	151, 330. 00	Job site.
Furnace slag	Tennessee Copper Co.	do	2, 700. 00	Copperhill.
Structural steel, rivets, etc.	Anthracite Bridge Co.	do	6, 517. 00	Newport.
Steam coal	Southern Coal Co., Inc.	July 11, 1942	4, 060. 00	Ewing.
Structural steel rollers	Roanoke Iron & Bridge Works.	July 17, 1942	1, 733. 00	White Pine.
Precast concrete roof and deck slabs.	Southern Cast Stone Co.	July 21, 1942	12, 465. 00	Douglas Dam.
Painting metal surfaces	Wailes-Dove Hermiston Co.	July 22, 1942	22, 398. 00	Installed.
Pit run furnace	Tennessee Products Corp.	do	3, 465. 00	Rockwood.
Magnetic starters	Graybar Electric Co., Inc.	do	857. 72	White Pine.
Burlap bags	M. M. Bosworth & Co.	July 24, 1942	12, 046. 00	Ewing.
Pipe	The Tri-State Pipe Co.	July 25, 1942	8, 240. 00	Do.
Aggregate	American Limestone Co.	July 27, 1942	12, 340. 00	Newport.
Nails	Wheeling Steel Corp.	July 30, 1942	2, 621. 20	Ewing.
Filler metal for intake gate guides.	Eagle-Picher Sales Co.	Aug. 6, 1942	2, 157. 00	Do.
Lumber	Burke & Hodges Lumber Co.	Aug. 7, 1942	1, 235. 00	White Pine.
Stone chips and bituminous seal coat.	American Limestone Co.	Aug. 13, 1942	3, 264. 00	Sevierville.
Structural steel	Carolina Steel & Iron Co.	Aug. 14, 1942	17, 397. 00	Newport.
Tar	Gamble Construction Co.	Aug. 18, 1942	8, 159. 00	Job-site.
Coal tar pitch	Reilly Tar & Chemical Corp.	do	56, 800. 00	Ewing.
Stone chips	American Limestone Co.	Aug. 20, 1942	2, 150. 00	White Pine.
Pipe railings, posts, etc.	Atlas Pipe Railing Co., Inc.	do	983. 00	Do.

TABLE 49.—*Major purchases of material and equipment*—Continued

Item	Vendor	Date of award	Contract price	F. o. b.
STRUCTURAL—Con.				
Miscellaneous steel	Carolina Steel & Iron Co.	Aug. 24, 1942	$897.00	Dandridge.
Gravel and coarse aggregates.	Knoxville Sangravl Material Co.	Sept. 3, 1942	8,750.00	White Pine.
Construction of superstructure.	Nashville Bridge Co.	Sept. 5, 1942	263,076.00	Job site.
Metal plate guards and appurtenances.	Tuthill Spring Co.	Sept. 10, 1942	8,492.00	White Pine
Pipe and pipe fittings	American Radiator & Standard Sanitary Corp.	do	2,113.48	Do.
Chain link fence, barbed wire, and gates.	American Chain & Cable Co.	Sept. 15, 1942	5,159.35	Ewing.
Valves and wrenches	National Cast Iron Pipe Co.	Sept. 18, 1942	584.01	White Pine.
Pipe fittings and pipe	U. S. Pipe & Foundry Co.	do	18,508.70	Do.
Crushed stone	American Limestone Co.	Sept. 24, 1942	2,150.00	Do.
Nails	Republic Steel Corp.	Sept. 25, 1942	1,572.48	Do.
Shortleaf yellow pine	W. P. Brown & Sons Lumber Co.	Oct. 9, 1942	2,245.00	Do.
Do	Wood Lumber Co.	do	4,777.50	Do.
Structural steel gage hoist rails.	Tennessee Coal, Iron & Railroad Co.	Oct. 16, 1942	1,037.92	Ewing.
Coarse aggregate	American Limestone Co.	Nov. 18, 1942	3,240.00	White Pine.
Do	Knoxville Sangravl Material Co.	Nov. 25, 1942	5,250.00	Do.
Crushed stone	American Limestone Co.	Dec. 2, 1942	9,650.00	Rankin.
Used black pipe	Columbus Pipe & Equipment Co.	Dec. 11, 1942	1,487.50	Ewing.
Spiral stairs and hatch covers.	Birmingham Ornamental Co.	Jan. 22, 1943	586.00	Do.
MECHANICAL				
Gage valves	Grinnell Co., Inc.	Feb. 3, 1942	4,137.55	Sevierville.
Air hose and packing	Tennessee Mill & Mine Supply Co.	do	2,762.74	Douglas Dam.
Pipe fitting tools	House-Hasson Hardware Co.	Feb. 4, 1942	521.56	Do.
Do	Young & Vann Supply Co.	do	754.18	Do.
Bits and accessories	Sullivan Machinery Co.	Feb. 5, 1942	5,135.55	Jefferson City.
Pipe fittings	Noland Co., Inc.	Feb. 6, 1942	543.29	Douglas Dam.
Bolts and nuts	Ross Bolt & Nut Co.	Feb. 7, 1942	1,570.08	Do.
Conveyor drives	Link-Belt Co.	Feb. 9, 1942	5,957.55	Sevierville.
Slide gates	Hardie-Tynes Manufacturing Co.	do	335,200.00	Do.
Traveling gate hoists	Philips & Davies	do	95,000.00	Do.
Twin strainers	Eliott Co.	do	1,827.00	Do.
Oil purifiers	DeLaval Separator Co.	Feb. 10, 1942	7,095.00	Do.
Gas engine generator	Buffalo Gasoline Motor Co.	do	9,678.00	Do.
Draft tube gates	Worden-Allen Co.	Feb. 11, 1942	7,787.00	Do.
Plumbing materials	American Radiator & Standard Sanitary Corp.	do	2,041.87	Jefferson City.
Radial gates	Lakeside Bridge & Steel Co.	Feb. 13, 1942	158,620.00	Sevierville.
Intake gate hoists and parts.	do	do	59,750.00	Do.
Crane	do	do	224,895.00	Do.
Sluice gate oil system pumps.	Quimby Pump Co.	Feb. 16, 1942	2,524.00	Do.
Steel tanks	Chattanooga Boiler & Tank Co.	Feb. 17, 1942	6,474.46	Do.
Machine shop equipment	W. S. Murrian Co.	Feb. 18, 1942	12,791.11	Do.
Turbines and governors	Woodward Governor Co.	Feb. 19, 1942	79,880.00	Do.
Do	S. Morgan Smith Co.	do	907,800.00	Do.
Intake gates	Philips & Davies	do	99,999.00	Do.
Station drain pumps	Peerless Pump Division	do	2,994.08	Do.
Spillway gate dogging devices.	Philips & Davies	do	25,300.00	Do.
Safety equipment	American Optical Co.	do	852.00	Do.
Do	C. D. Genter Co.	do	500.00	Douglas Dam.
Machine shop equipment	Noland Co.	Feb. 21, 1942	1,049.00	Sevierville.
Do	Bryant Machinery & Engineering Co.	do	3,820.00	Do.
Pumping units	Ingersoll-Rand Co.	Feb. 24, 1942	705.20	Jefferson City.
Air compressors	Sullivan Machinery Co.	do	4,136.00	Sevierville.
Conveyor brush outfits	Robbins Conveying Belt Co.	Feb. 26, 1942	925.00	Do.
Conveyor machinery	Webster Manufacturing Co.	do	12,079.88	Do.
Conveyor belting	Boston Woven Hose & Rubber Co.	do	14,962.67	Do.
Heating, ventilating, and air conditioning.	American Air Filter Co.	Mar. 2, 1942	787.60	Do.

TABLE 49.—*Major purchases of material and equipment*—Continued

Item	Vendor	Date of award	Contract price	F. o. b.
MECHANICAL—Con.				
Valves, fittings, pipe and accessories	Tennessee Metal Culvert Co.	Mar. 3, 1942	$1,125.86	Sevierville.
Fans for heating and ventilating.	Leinart Engineering Co.	Mar. 5, 1942	1,055.25	Do.
Bushing stock	Thos. F. Seitzinger's Sons	do	3,427.20	Jefferson City
Pipe, valves, and fittings	American Radiator & Standard Sanitary Corp.	Mar. 9, 1942	7,499.33	Do.
Plumbing fixtures and pump.	do	do	1,119.52	Douglas Dam.
Valves, fittings, pipe, and accessories.	Tennessee Metal Culvert Co.	do	1,866.78	
Do	U. S. Pipe & Foundry Co	do	1,479.04	
Do	Crane Co	do	1,643.28	
Do	Grinnell Co	do	1,439.85	
Plumbing fixtures	Fowler Bros. Co	Mar. 10, 1942	637.60	Sevierville.
Structural steel	Worden-Allen Co	Mar. 12, 1942	8,118.00	Do.
Cooling coils	American Blower Co	do	841.50	Do.
Fans for heating and ventilating.	The New York Blower Co	Mar. 13, 1942	4,787.36	Do.
Pipe	Inter-State Foundry & Machine Co.	Mar. 18, 1942	1,878.00	
Do	Naylor Pipe Co	do	1,326.30	
Do	American Radiator & Standard Sanitary Corp.	do	801.19	Do.
Do	American Cast Iron Pipe Co.	do	3,253.81	Do.
Do	Merco Nordstrom Valve Co.	do	1,945.52	Do.
Do	Crane Co	do	1,653.02	Do.
Do	Chapman Valve Manufacturing Co.	do	1,713.75	Do.
Do	Leinart Engineering Co	do	722.45	Do.
Dragline and bucket	Wilson-Weesner-Wilkinson Co.	Mar. 19, 1942	14,718.00	Jefferson City.
Centrifugal pumps	Allis-Chalmers Manufacturing Co.	Mar. 20, 1942	2,768.00	Do.
Automatic elevator	Warner Elevator Manufacturing Co.	Mar. 23, 1942	16,725.00	Sevierville.
Water cooling system	Airtemp Construction Co	Mar. 25, 1942	5,520.00	Do.
Electric air heaters and auxiliary equipment.	Electric Air Heater Co	do	2,319.50	Do.
Do	Wesix Electric Heater Co	do	2,189.02	Do.
Oil pumps	Worthington Pump & Machinery Corp.	Mar. 28, 1942	1,331.00	Do.
Pipe	American Cast Iron Pipe Co.	Apr. 3, 1942	141.80	Do.
Do	do	do	3,116.46	Do.
Do	Noland Co	do	3,889.89	Do.
Do	Crane Co	do	894.55	
Do	American Radiator & Standard Sanitary Corp.	do	5,941.51	
Arc welding machines	General Electric Co	Apr. 8, 1942	3,573.00	Douglas Dam.
Insulating materials	Johns-Manville Sales Corp.	Apr. 10, 1942	2,771.08	Sevierville.
Welding machines	The Lincoln Electric Co	Apr. 13, 1942	1,135.91	Douglas Dam.
Lifting chains for intake and gates.	Baldt Anchor, Chain & Forge Co.	Apr. 20, 1942	15,514.40	Sevierville.
Steel	C. M. McClung & Co	Apr. 22, 1942	2,428.98	Do.
Pipe fittings	American Radiator & Standard Sanitary Corp.	do	670.34	Douglas Dam.
Service bay crane	Chicago Tramrail Co	May 5, 1942	1,690.00	Sevierville.
Chains for draft tube gates.	S. G. Taylor Chain Co	May 6, 1942	1,003.00	Do.
Valves, fittings, pipe, and accessories.	Noland Co	May 23, 1942	1,383.38	Do.
Do	do	May 26, 1942	4,270.60	Do.
Do	American Radiator & Standard Sanitary Corp.	do	3,821.12	Douglas Dam.
Electric welder	Electric Arc, Inc	May 27, 1942	850.00	White Pine.
Transformer transfer car	Atlas Car & Manufacturing Co.	May 28, 1942	3,215.00	Ewing.
Guard and dampers, access doors.	Leinart Engineering Co	June 10, 1942	885.25	
Timber	City Lumber Co	June 11, 1942	1,032.48	Douglas Dam.
Valves, fittings, pipe, and accessories.	National Cast Iron Pipe Co.	June 16, 1942	1,903.96	Ewing.
Pumps	Fairbanks, Morse & Co	do	3,827.00	Do.
Sewage ejectors and sump pump.	Yoeman Bros	June 26, 1942	2,708.00	Do.
Valves, fittings, pipe, and accessories.	Chapman Valve Manufacturing Co.	do	2,485.00	Dandridge.

TABLE 49.—*Major purchases of material and equipment*—Continued

Item	Vendor	Date of award	Contract price	F. o. b.
MECHANICAL—Con.				
Valves, fittings, pipe, and accessories.	National Cast Iron Pipe Co.	June 26, 1942	$977.27	Dandridge.
Lubricating oil	The Texas Co.	July 13, 1942	3,188.00	Ewing.
Pipe insulation	Armor Insulating Co.	July 23, 1942	1,791.83	Do.
Control equipment	Leinart Engineering Co.	Aug. 17, 1942	652.63	Do.
Valves, fittings, pipe, and accessories.	Hajoca Corp.	Sept. 26, 1942	654.93	Dandridge.
Do	American Cast Iron Pipe Co.	do	1,665.30	Do.
Machine shop equipment	Tennessee Mill & Mine Supply Co.	Oct. 5, 1942	805.06	
Do	C. M. McClung & Co.	Oct. 13, 1942	605.57	
Instruction tags	George J. Mayer Co.	Jan. 28, 1943	1,522.00	Ewing.
Pumping unit	Peerless Pump Division	Apr. 2, 1943	1,651.82	Do.

Appendix F

CONSTRUCTION EQUIPMENT

Table 50.—*Classification of construction equipment*

Equipment	Number of units	Size or capacity	Model	Power	Approximate total cost new
HAULING CLASSIFICATION					
Locomotives:					
American	1	73 tons	0-3-0	Steam	$8,000
Baldwin	2	do	do	do	8,000
Davenport	1	10 tons	0-4-0	Diesel	5,650
Plymouth [1]	2	18 tons	JLB-18	Gas	18,800
Do	2	9 tons	DLE-8	Gas electric.	9,400
General Electric [1]	3	25 tons	IGE-733	Diesel electric.	39,400
Tractors:					
Allis-Chalmers [1]	3	108 horsepower	HD-14	Diesel	22,000
Caterpillar	25	110 horsepower	D-8	do	180,000
Do.[1]	2	25 horsepower	D-2	do	6,180
Cleveland	8	96 horsepower	FDL	do	58,800
International [1]	2	30 horsepower	TD-6	do	5,200
Trac trucks:					
Euclid	15	16 cubic yards	F-9FDT	do	175,000
Do.[1]	4	do	do	do	46,800
Linn crawlers [1]	15	8 cubic yards	6A-10	Gas	153,700
Trucks, dump:					
Federal	4	6 cubic yards	65	do	22,000
Koehring [1]	4	do	WD-60	Diesel	46,200
White [1]	4	do	WA-34	Gas	19,300
Euclid	9	10 cubic yards	5 FD	Diesel	103,000
Hug	12	12 cubic yards	D99S	do	118,800
Sterling [2]	5	do	HCS-297	do	62,500
Trucks, stake:					
Ford and Chevrolet	5	1.5 tons		Gas	5,000
Reo	1	3 tons	21 BHS	do	1,650
White	1	do	Winch and derrick.	do	3,890
International	1	4 tons	D-50	do	1,900
GMC	3	5 tons	AC704	do	6,900
Federal [1]	1	do	20K	do	1,900
Trucks:					
Ford (mixer) [3]	2	3 tons	V-8	do	2,100
GMC (mixer) [3]	3	do	AC-402	do	3,150
GMC (fuel tank) [1]	1	do	CC-402	do	2,550
Do	1	do	CC-402	do	2,500
Truck trailers:					
Fruehauf	1	5 tons	P-7		580
Roger	1	40 tons	D-40		4,300
Do	1	75 tons	D-75		6,600
Crawler wagons:					
Athey	7	16 cubic yards	FC-31		37,400
Do.[1]	10	do	FC-31		60,000
Car, railroad, flat:					
Birmingham	1	50 tons			1,000
Haffner-Thrall	6	40 tons			6,500
Wagons: Lumber, Owensboro	16	8 tons			1,600
AIR AND DRILLING CLASSIFICATION					
Diamond core drills: Sullivan [4]	18	2⅛ inches	12	Gas	27,000
Shot core drills:					
Ingersoll-Rand	2	36 inches	WF-3	do	14,200
Do	1	do	WS-3	Electric	4,300
Drills, rock:					
Ingersoll-Rand, drifters	20	1¼ by 5 inches	X71	Air	8,000
Chicago Pneumatic, drifters	8	do	70	do	3,500
Gardner-Denver, drifters	10	do	D99	do	4,000
Ingersoll-Rand, jackhammer	16	1-inch hexagon	S49	do	3,200
Gardner-Denver, jackhammer	38	do	S55	do	7,600

See footnotes at end of table.

TABLE 50.—*Classification of construction equipment*—Continued

Equipment	Number of units	Size or capacity	Model	Power	Approximate total cost new
AIR AND DRILLING CLASSIFICATION—Continued					
Drills, portable:					
Chicago Pneumatic	4	1¼ inches	36R	Air	$700
Thor	1	do	8	do	175
Ingersoll-Rand	7	2 inches	90	do	1,700
Thor [1]	9	do	9-S	do	2,200
Air hoists:					
Gardner-Denver [3]	10	1 drum	HK	do	4,200
Do	3	do	HB	do	900
Ingersoll-Rand	4	do	HU	do	1,900
Grinders, portable:					
Ingersoll-Rand	2	5 inches	4G	do	200
Chicago	3	6 inches	331-P	do	300
Ingersoll-Rand	6	8 inches	4GV8	do	700
Paving breakers:					
Gardner-Denver	8	1¼ by 6 inches	B72H	do	1,600
Ingersoll-Rand	7	do	CC45	do	1,290
Clay diggers: Ingersoll-Rand	8	5 inches	73	do	800
Rivet hammers:					
Chicago Pneumatic	20	1$\frac{1}{16}$ inches	90	do	1,500
Ingersoll-Rand	2	do	90	do	150
Backfill tampers: Ingersoll-Rand	3		34	do	300
Impact wrenches:					
Chicago Pneumatic [1]	5	½ to ¾ inch	365R	do	870
Ingersoll-Rand	9	1¼ inches	533	do	2,250
Do	4	1¾ inches	555	do	2,100
Sump pumps:					
Chicago Pneumatic	8	2 by 2½ inches	CP-7	do	1,400
Thor [1]	8	do	361-T	do	1,400
Ingersoll-Rand [1]	9	do	25	do	1,500
Compressors, stationary:					
Sullivan	2	3,000 cubic feet per minute.	WN-4	Electric	44,000
Bury	1	1,300 cubic feet per minute.	VCC-4B	do	1,950
Compressors, portable:					
Worthington	2	160 cubic feet per minute.		Gas	5,600
Chicago Pneumatic	1	315 cubic feet per minute.	315	Diesel	4,900
Ingersoll-Rand	1	do	315A	do	4,700
Worthington	3	do	315	do	12,600
Ingersoll-Rand	1	500 cubic feet per minute.	K-500	do	7,800
Air receivers:					
Ingersoll-Rand	1	3 by 8 feet	HM		220
Pennsylvania	1	3½ by 10 feet	HM		340
Chattanooga Boiler	1	4 by 10 feet	VM		170
Pennsylvania	1	5½ by 30 feet	HM		1,600
EXCAVATING, SURFACING, AND GRADING CLASSIFICATION					
Ditcher, Parsons (rented 1 month)	1		40	Gas	
Roller, sheepsfoot:					
TVA shopmade	1				1,000
Euclid	7	2 drums	8M		6,000
LeTourneau	2	do	Y2		1,700
Scrapers, LeTourneau	7	12 cubic yards	LP-12		33,500
Shovels, crane:					
Insley [1]	2	½ cubic yard	K-12	Gas	13,800
Lima [3]	1	1¼ cubic yards	550	Diesel	17,500
Northwest	2	1½ cubic yards	6	do	30,700
Lorain	1	1¾ cubic yards	80	do	31,800
Bucyrus-Erie	2	2 cubic yards	44-B	do	56,600
Lorain [1]	3	do	82	do	78,000
Osgood (rented)	1	½ cubic yard		Gas	
Graders, elevating:					
Adams [1]	2	4 by 25 feet	11	Diesel	10,300
Caterpillar [1]	2	do	48	do	10,800
Grader, Autopatrol:					
Adams	1	12 feet	511	do	5,400
Caterpillar [1]	1	do	12	do	6,300

See footnotes at end of table.

TABLE 50.—*Classification of construction equipment*—Continued

Equipment	Number of units	Size or capacity	Model	Power	Approximate total cost new
EXCAVATING, SURFACING, AND GRADING CLASSIFICATION—Continued					
Grader, leaning wheel: Adams	1	12 feet	125	Towed	$1,960
Bucket, clamshell:					
Blaw-Knox [1]	1	½ cubic yard	065		800
Owen [1]	1	do	126		770
Williams	1	¾ cubic yard	Special		580
Erie	1	1½ cubic yards	55		900
Owen [1]	1	do	M-146		1,330
Williams	1	2 cubic yards			1,740
Buckets, dragline:					
Insley [1]	2	½ cubic yard	44851		680
Hendrix [1]	2	1½ cubic yards	TS		780
Williams	1	1 cubic yard	DF		460
Erie	1	do	GX-3		515
Bucyrus-Erie	1	2 cubic yards	AY		1,220
Scarifiers, LeTourneau	2		H-3		2,600
Tar heaters:					
Littleford	6	550 gallons	83		3,750
Standard steel	2	525 gallons	DH		1,200
Disc harrows:					
Rome	9	26 inches			4,000
Athens	3	do			1,500
HOISTING CLASSIFICATION					
Cranes, gantry:					
American	1	40 tons	10125	Electric	52,300
Clyde	2	do	28-E-125	do	115,000
Dravo	1	do	AE	do	42,000
Locomotives:					
American	1	25 tons	5	Diesel	21,000
Industrial Brownhoist [3]	1	35 tons	DD-8	Steam	14,500
Crane, car:					
Silent hoist	1	2½ tons	AX	Gas	5,600
LeTourneau (tractor)	1	10 tons	AD-3	do	1,470
Derrick, stiffleg, Bedford [3]	1	20 tons		Electric	3,340
Hoist:					
American (60 horsepower) [3]	1	2 drums	FCD	do	2,230
National (60 horsepower) [3]	1	do	FCD	do	1,770
American (60 horsepower) [3]	1	do		Gas	1,550
Clyde (54 horsepower)	1	do	FCD	do	1,450
Construction Machinery Company (40 horsepower).	1	do	DD-609	do	1,000
Lidgerwood (72 horsepower) [3]	1	do		do	1,750
American (40 horsepower)	1	do	FCD	Steam	1,160
PUMPING AND COFFERDAM CLASSIFICATION					
Pile hammers: McKiernan-Terry	2	1,600 pounds	9B3	do	3,400
Pumps, force:					
Novo, 25 gallons per minute at 175 pounds.	2	3 by 4 inches	DU-672	Gas	600
Do [1]	6	do	DU-672	do	2,160
Gould, 25 gallons per minute at 100 pounds.	1	do	63A	do	300
Pumps, centrifugal:					
American, 7,000 gallons per minute at 100-foot head [3].	1	14 by 14 inches	14-DS-MB	Electric	2,300
American Marsh, 5,000 gallons per minute at 50-foot head.	1	12 by 12 inches	HLM	do	1,600
Allis-Chalmers, 1,300 gallons per minute at 20-foot head.	2	6 by 6 inches	S	do	300
Allis-Chalmers, 2,300 gallons per minute at 200-foot head.	1	8 by 8 inches	S	do	450
Allis-Chalmers, 2,250 gallons per minute at 110-foot head.[3]	2	do	HC-SF	do	2,080
Allis-Chalmers, 3,000 gallons per minute at 210-foot head.	1	10 by 8 inches	SH	do	3,200
Allis-Chalmers, 4,000 gallons per minute at 60-foot head.	2	12 by 12 inches	S	do	2,660
Byron-Jackson, 4,000 gallons per minute at 60-foot head.	1	12 by 10 inches	VC-S-SE	do	2,750
Do	1	12 by 12 inches	6A	do	3,240

See footnotes at end of table.

TABLE 50.—*Classification of construction equipment*—Continued

Equipment	Number of units	Size or capacity	Model	Power	Approximate total cost new
PUMPING AND COFFERDAM CLASSIFICATION—Continued					
Pumps, centrifugal—Continued					
Byron-Jackson, 5,985 gallons per minute at 50-foot head.	11	16 by 16 inches	VC-SSI	Electric	$28,000
Cameron, 4,200 gallons per minute at 275-foot head.[3]	1	12 by 10 inches	ALV	do	2,780
Cameron, 4,000 gallons per minute at 138-foot head.[3]	1	do	AFVS	do	1,700
Chicago, 18,000 gallons per minute at 90-foot head.[3]	1	18 by 18 inches	HBBLLC	do	2,410
Dayton-Dowd, 4,800 gallons per minute at 38-foot head.[3]	2	10 by 10 inches	VC-SSI	do	2,400
Dayton-Dowd, 4,800 gallons per minute at 60-foot head.[3]	2	14 by 12 inches	CS-SP	Gas	5,100
Dayton-Dowd, 7,500 gallons per minute at 80-foot head.[3]	1	20 by 18 inches	CS-SC	Electric	1,180
Dayton-Dowd, 9,000 gallons per minute at 60-foot head.[3]	1	do	AX-22	do	2,010
Dayton-Dowd, 9,200 gallons per minute at 80-foot head.[3]	2	do	A-25	do	4,600
Fairbanks-Morse, 1,490 gallons per minute at 125-foot head.	1	6 by 6 inches	5813	do	1,300
Fairbanks-Morse, 5,000 gallons per minute at 60-foot head.	3	16 by 14 inches	VC-S-SI	do	5,700
Gould, 2,500 gallons per minute at 110-foot head.[1]	2	8 by 8 inches	3601	Gas	4,050
Morris (sand)	1	6 inches	7X7	Electric	75
Morris, 3,000 gallons per minute at 120-foot head.	1	12 inches	Sump	do	1,430
Morris, 5,000 gallons per minute at 60-foot head.	3	14 by 12 inches	VC-SSI	do	10,650
Peerless, 1,450 gallons per minute at 400-foot head.	3	10 by 10 inches	VC-10SI	do	12,500
Pomona, 150 gallons per minute at 400-foot head.	1	6 inches	XLC	do	1,440
Worthington, 1,480 gallons per minute at 140-foot head.	1	10 by 10 inches	VC-2SI	do	1,200

(There were about 20 additional smaller pumps used on this project.)

Equipment	Number of units	Size or capacity	Model	Power	Approximate total cost new
CONCRETING CLASSIFICATION					
Cement pump: Fuller-Kenyon	1	6 inches	C	Electric	4,330
Cement shovel: Webster	1		Scoop	do	900
Cement silo: Stupp Bros	1	6,000 barrels	Steel		6,400
Concrete buckets:					
Heltzel	2	1 cubic yard			200
Johnson	12	2 cubic yards			6,000
Dravo	4	3 cubic yards			2,500
Do.[4]	17	4 cubic yards			14,500
Concrete mixers, portable:					
Kwik-Mix	1	6 cubic feet	6S	Gas	600
Construction Machinery Co	1	14 cubic feet	14S	do	1,500
Master	1	do	14S	do	1,500
Jaeger	1	do	14S	do	1,600
Grout mixers: Colonial	9	19 cubic feet		Air	5,000
Grout pumps:					
Gardner-Denver	5	3 inches	Duplex	do	2,300
Do.[1]	9	do	do	do	3,800
Vibrators, concrete:					
Mall and Viber	25		Flexible shaft	Electric	8,500
Electric Tamper & Equipment Co.[1]	44		Spade	do	16,250
Do	4		Pudler	do	2,000
Frequency converter:					
Westinghouse	1	15 kilowatts	1-98M	do	500
General Electric	2	30 kilowatts	5MM	do	1,800
SHOP CLASSIFICATION					
Machine shop:					
Bender, bar, Ryerson-Kling	1	1¼ and 1½ inches	1	do	2,222
Bender, bar, Kardong[1]	1	1¼ inches	C	do	700
Bender, pipe, Watson-Stillman	1	1½ to 4 inches	1791-B	Hydraulic	493

See footnotes at end of table.

TABLE 50.—*Classification of construction equipment*—Continued

Equipment	Number of units	Size or capacity	Model	Power	Approximate total cost new
SHOP CLASSIFICATION—Con.					
Machine shop—Continued					
Bender, pipe, Greenlee	1	1 to 3 inches	770	Hydraulic	$128
Bender, brake, Dreis-Krump	1	8 feet	1112	Manual	361
Bender, form, Hendley-Whitmore	1	do	11A	do	1,002
Cutter, bar, Royersford	1	2 inches	3	Electric	1,895
Cutter, bar, Beloit [1]	1	do	66	Manual	185
Cutter, cable, Upson-Walton	1	1¼ inches	4	do	265
Drill press, radial, Desser	1	40 inches		Electric	1,986
Drill press, vertical, Cincinnati-Bickford.	1	24 inches	CB-21	do	484
Drill press, vertical, Buffalo	1	17 inches	16	do	200
Drill press, vertical, Barnes	1	26 inches	B-24	do	550
Forges, Hauk	2		H362	Oil	360
Grinders, bench, Black & Decker	3	6 to 8 inches		Electric	140
Grinders, bench, U. S.	4	10 inches		do	490
Grinder, bench, Van Dorn	1	do	U-83	do	92
Grinders, pedestal, U. S.	2	12 inches	10	do	475
Grinders, pedestal, Cincinnati	1	do	108	do	179
Grinder, pedestal, Cincinnati [1]	1	do	500	do	169
Hammer, forging, Erie	1	1,100 pounds		Air	3,300
Lathe, Rahn	1	18-inch swing	B17	Electric	350
Lathe, LeBlond	1	20-inch swing	HD	do	1,550
Do	1	19 inches/38 inches	Gap	do	5,718
Lathe, Rahn	1	24 inches/36 inches	Gap	do	2,399
Press, Manley	1	60 tons	26-A-49	Hydraulic	319
Saws, hack, Marvel	2	10 by 6 inches	9	Electric	2,100
Saw, hack, Marvel	1	8 by 6 inches	2	do	183
Saws, hack, Kelley [1]	2	10 by 10 inches	10	do	1,064
Shaper, Gould and Eberhardt	1	24 inches	ADJ	do	1,287
Threader, bolt, Landis	1	½ to 1½ inches	ADJ	do	3,046
Threader, pipe, Beaver	1	2 inches	44A	do	259
Threader, pipe, Landis	1	2½ inches	C-61-4	do	3,150
Threader, pipe, Oster	1	1 inch	304B	do	1,015
Threader, pipe, Toledo	1	2 inches	999	do	296
Carpenter shop:					
Lathe, Oliver	1	12 inches	159A	do	345
Planer and matcher, Newman [1]	1	14 by 6 inches	500	do	5,899
Planer, Oliver	1	16 inches	166	do	767
Do	1	24 inches	299	do	1,532
Saw, band, Oliver	1	36 inches	116D	do	1,146
Saw, cut-off and rip, Fay and Egan.	1	16 inches	264	do	1,112
Saw, combination, DeWalt	1	do	GM-69	do	542
Do [1]	1	do	GE-JR	do	550
Saw, swing, Oliver	1	do	136	do	318
Saws, portable, hand	5	6 to 8 inches			450
Garage:					
Valve grinder, Sioux	1		868	Electric	243
Valve grinder, Hall	1		ES	do	296
Pumps, gas dispensing, Wayne	2			do	335
Pump, gas dispensing, Tokheim	1			do	189
Pumps, gas dispensing, Blackmer	2			do	430
Pump, gas dispensing, Bowser	1			do	152
MISCELLANEOUS CLASSIFICATION					
Paint spray, DeVilbiss	2			Air	1,500
Portable drills, various makes	35	¼ to ¾ inch		Electric	2,500
Masonry saw, Felker	1	8 inches	11K	do	361
Boiler, Farquhar	1	60 horsepower	Vertical		1,098
Boiler, Pennsylvania	1	150 horsepower	Horizontal		1,500
Boiler, Marion	1	50 horsepower	do		870
Tank, steel, water [6]	1	7,000 gallons			360
Tanks, steel, gasoline	2	12,000 gallons			1,000
Tanks, steel, oil	2	15,000 gallons			1,700
Water cooler, York	1	4 tons	D-6	Electric	1,440
Water coolers, Frick	2	do	HA	do	2,150
Welders, Lincoln	5	300 amperes		do	2,500
Welders, General Electric	7	do		do	3,500
Do	3	do		Gas	3,600
Do	3	do		Diesel	4,900

[1] Purchased new at Douglas Dam.
[2] 3 units purchased new at Douglas Dam.
[3] Purchased used at Douglas Dam.
[4] 6 units purchased new at Douglas Dam.
[5] 8 units purchased new at Douglas Dam.
[6] Second-hand tank purchased for Douglas Dam.

Appendix G

CONSTRUCTION DRAWINGS

"Drawings for the Douglas Project" will be issued separately by the Tennessee Valley Authority as a technical monograph. This publication, when issued, will contain approximately 100 selected drawings and a list of all drawings prepared for the project.

Bound volumes of drawings for several major projects may be obtained, when available, from the Treasurer of the Tennessee Valley Authority, Knoxville, Tenn.

Technical monograph

34.	"Plans and Specifications for the Norris Dam" (1946)	$2.50
41.	"Drawings for the Pickwick Landing Project" (1948)	2.50
50.	"Drawings for the Chickamauga Project" (1948)	2.50
56.	"Drawings for the Nottely and Chatuge Projects" (1946)	1.00
57.	"Drawings for the Apalachia Project" (1947)	2.50
58.	"Drawings for the Ocoee No. 3 Project" (1947)	2.00
59.	"Drawings for the Watts Bar Steam Plant" (1948)	2.50
60.	"Drawings for the Cherokee Project" (1947)	2.50
61.	"Drawings for the Watts Bar Project" (1948)	2.50

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